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Rob Roggema

Swarm Planning

The Development of a Planning Methodology to Deal with Climate Adaptation

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Supervisor's Foreword

It was less than 10 years ago when spatial planning was entirely ignorant of issues related to climate change and energy. The world had been comfortably served by means of fossil fuels, which are extracted from the earth in specific places, but afterwards can be transported easily to any generic place across the globe. Even longer than the fossil-based Industrial Revolution the earth's climate has been relatively friendly since roughly 10,000 years ago—mind you, the period during which all human civilisations evolved. During this timeframe, humans have learned to react to the whims of their climate and versatile weather, mainly by combating these or avoiding dangerous sites.

For those who may have been living under a stone: that period is over now.

The world's climate—already positioned between two ice ages, so close to geologic summer—is now with near certainty severely influenced by man. Exponential growth and growing prosperity have led to a throughput of energy resources and emission of greenhouse gases unprecedented in history, and still increasing. At present some 'new' strongly polluting fossil resources (tar sands and shale gas) stretch the debate of energy prospects, but everyone knows that even the deployment of these fuels cannot save the Fossil Age. With underground packages of mega-joules depleting, renewable sources need to fill in the needs of generations. And these can only be won at the earth's surface.

Here the battle for space starts: conversion, storage and transport of renewables will compete with spatial functions as agriculture and nature, leisure and living. New Planning involves energy as a decisive factor for landscape design and spatial organisation.

The indirect effect of energy has also encouraged another element to be included in spatial planning: climate adaptation. Expected increase of sea levels and storm water discharge, hurricanes and typhoons, droughts and bushfires are so beyond the imaginary that traditional solutions will soon (perhaps a few or more decades…) become obsolete. Adaptation is the new hope; not fighting the human-incited power of nature, however dealing with its devastating effects in a benign way, and perhaps even trying to merit from climate change.

I was very lucky that in the year 2005 Rob Roggema drew me into an unexpected joint voyage that would explore the new scientific area of energy potential mapping and climate adaptive planning. As strategic manager of the Dutch province of Groningen, Rob incited a range of studies in the area of energy and climate that generated new insights, methods and solutions. Groningen probably was the first region in the world that had a Master Plan for a society fully run on sustainable energy and spatially ready for climatic extremes.

As so often, reality turned a different path after Rob's departure and Groningen now hosts two new giant power plants run on fossils.

A Dutchman used to the struggle with water from three sides (sea, sky and continent) he is now working in Australia, a country experiencing the freak excrescence of climate change in different directions: extreme temperatures, bushfires and floods. This may seem a different narrative but the Swarm Planning method Rob developed can be used everywhere, so probably better execute it where the urgency is most strongly felt. With the experience of the two countries, Rob finished his excellent Ph.D. research on Climate Adaptive Planning, an enterprise he managed to do alongside his other work.

This book is the outcome of that doctoral work, for which Pavel Kabat and I were the fortunate supervisors. It is a great accomplishment of Rob Roggema. Moving faster than most scientists in this area, he has crossed the Rubicon to merge spatial planning with climate adaptation, meanwhile illustrating how an urgent necessity can also be turned into something attractive.

The future is not totally doomed.

Savour the flavour of positive and proactive planning—hop on the same voyage, learn and enjoy. This Doctoral thesis is accepted by the supervisors, on behalf of the College for Doctoral Graduations, 15 May 2012.

Delft, January 2013 Andy van den Dobbelsteen

Acknowledgments

In my opinion it is an important task of science to initiate new developments and to discover new routes. Therefore, I view conducting doctoral research not only as a process to prove the candidate's ability to independently conduct scientific research, but also as a way to chase innovations and come up with new solutions. This thesis is the result of a quest for both.

During, and also before, executing this doctoral research many people supported me in achieving my goals. And this was not always a joyful experience for those involved. Because my initial urge would always be to look for new solutions, without accepting existing answers. This means that in the collaboration with others it is crucial to be able to operate on the basis of equivalence, to set aside hierarchical positions. A boss, who plays the boss because he is the boss, creates inequality. Hence makes collaboration more complicated. The employee, who just follows and does what the boss tells him to, also frustrates collaboration. With everyone I mention here I have found a high level of equivalence.

Jón Kristinsson was the first to kindle the desire for research in me. He gave me confidence and trust and after a couple of weeks he sent me to Taiwan for a conference. Very special! Apologies to you Jón, at the time I couldn't convert this beautiful start into finalising my Ph.D..

Later, during the Grounds for Change project the wish to conduct scientific research became prevalent again. I enjoyed the collaboration with Andy, Kees, Sebastian, Sanjay and many others a lot. So much that the regional ministers at the provincial government in Groningen started to call me 'the intellectual'. Seemingly, the desire to research and to develop new concepts outpaced policymaking within a certain political context. Despite the fact that this attitude, within the walls of the governmental building, met with the usual tensions, Dick Bresser gave me the room to explore, to orientate myself externally and to go off the beaten track. He didn't have to mention that a second time! I connected with emerging themes such as energy and climate change. In the INCREASE conference series we developed, together with Abdulsalam, Wim, Sven, Tim, Gert-Jan, Victor, Sebastian, Andy and many others, new concepts to plan renewable energy sources in a spatial way. It occurred to me quite rapidly that the current spatial planning practice had severe difficulties with integrating these new developments in a meaningful way. The core theme of my research was found.

An important ‘tipping point’ appeared to be located in the Land van Kockanje (The country of Kockanje), a restaurant in the inner city of Groningen. It was a warm afternoon in 2005 and I had a very pleasant dinner with Dany Jacobs, professor strategic innovation at the University of Groningen. Via many U-turns, short cuts, wrong tracks and even more subjects we finally invented Swarm Planning, as a way to plan for something that is uncertain. What ultimately became this thesis announced itself.

I undertook my first explorations of Swarm Planning at the faculty of Spatial Sciences, University of Groningen. Quite rapidly it became clear to me that this was not the environment that would allow me to confidently pursue finalising my doctoral thesis. I stopped the research at that point, but the idea to develop a planning framework that is suitable for climate change and sustainable energy did not leave me. I was lucky to find in Delft University of Technology and Wageningen University and Research Centre the ideal combination of knowledge and context to finally start my research.

The design of a sustainable built environment, in which renewable energy plays an important role (TU), in combination with knowledge of climate change and water and ecological systems, and also Landscape Architecture (WUR) proved a fertile environment for my research. Andy and Pavel, both my promotors, allowed me the freedom to conduct the research in the way I wanted. You gave me, at important bifurcation points in the research, invaluable feedback, which always advanced the research with giant leaps. Wherever on the Globe we resided you were always there for advice, support and critique. No matter how short our conversations were, the impact was enormous every time! Moreover, in 2010 you gave me the room to accept a position as inaugural visiting research fellow in Melbourne; a change that still persists.

Early 2008 my research could finally take off. Meanwhile the then Ministry of Housing, Spatial Affairs and the Environment (which is now the Ministry of Infrastructure and the Environment, I&M) gave its support to the research (and not only financially). Pieter Bloemen and Meinte de Hoog supported aim and content of the research and made sure that it was linked with the National Program for Spatial Adaptation to Climate Change (ARK) within the ministry. Apart from this, close ties with the Climate Changes Spatial Planning (CCSP), in which the connection between Spatial Planning and Climate change was central, arose. Florrie and Marit, you played a crucial role in developing the Groningen-Drenthe projects, which contributed substantial amounts to my research: the Hotspot Groningen and the Hotspot Peat Colonies. Thank you for the high quality collaboration and very pleasant contacts! I would like to also thank my colleagues in the Program Board of CCSP for the often inspiring meetings in Amersfoort and the lively congresses, which happened with great regularity.

David and Twan, you taught me that it is possible to be boss without playing the boss solely because you are the boss. You knew how to deal with me and did not make yourself more important than the content of the case. This way we progressed and were able to find new ways. Ways that were necessary to deal with the problems of the future.

Erwin, you were always there to convert my higgledy-piggledy and twists of mind in beautifully designed products. The birth cards of Anouk, Inez and Micha, the winning submissions for design competitions, such as the Rising Tides Competition in San Francisco and this thesis are the living examples.

Herald, you were there from the beginning and followed all my wanderings. Often from a distance, sometimes close, but always full of questions and remarks. Truly the best reason to be there as paranymph during the public defence!

Wim, somewhere in the beginning of the 1990s Breda was the centre of the universe en we made war with the establishment of existing planners. Breda has not been the same since! Soon, we shared a passion for the complexity of spatial planning processes, each from our own point of view. And also our Kort Besteck, the columns, which Erwin graphically designed, for Duurzaam Bouwen, which invariably were conceived in the Groene Olifant (The Green Elephant), are a proof of our ‘one of a mind’. I am proud to have you next to me as second paranymph; the tails suit you prodigiously!

Finally, despite the fact that it is consuetudinary to illuminate your family at the end of this acknowledgement, I will do the same. Lisa, thank you a lot for all the support you gave me in the recent (and the coming as well) years. Wherever I went, my thoughts went, you were always there and always willing to think along, operate as native and give me a new insight along the way. Besides the love you give me, you are also an ambassador, never stopping to whoever wants to listen, start telling about Swarms and how they play a role in planning as well as in organisational change. Most beloved Anouk, Inez and Micha, I will end with the three of you, because you are the most important. Blessed with a strange dad, who wanted to conduct his Ph.D., you ended up living in Melbourne. Coincidentally, the city that is declared the most liveable city in the world for the second year in a row, since we started living here two years ago (Economist Intelligent Unit, 2012 www.eiu.com/liveability2012). By the way, there is no proof yet for a causal relation in this matter. You must have thought, every once in a while: “is he annoyed again with the enormously slow website of an academic journal, where uploading your article takes longer than writing it?” In any case, it is a joy to have you around me and to enjoy your smart little jokes!

Thank you all for the support in the years that lay behind (also for the ones I forgot to mention)!

Contents

Introduction

Climate Adaptation faces difficulties to be integrated in spatial planning. The consequence of this is that in spatial plans only few measures are taken to anticipate future climate change. This means that land use insufficiently is prepared for future impacts. In other words: the adaptive capacity in land use is low and could prove insufficient when the impacts of climate change become apparent. This thesis aims to identify a way to increase the adaptive capacity of land use through the creation of plans and designs, which increase the resilience of the landscape through what it is better prepared for future impacts of climate change.

The cause of the difficult integration of climate adaptation in spatial planning lies in the different characteristics of the both.

Climate adaptation is seen as a wicked problem (VROM-raad, 2007; Commonwealth of Australia, 2007) or even a super-wicked one (Lazarus, 2009). Rittel & Webber (1973) described these kinds of problems as ‘a class of social system problems, which are ill-formulated, where the information is confusing, where there are many clients and decision makers with conflicting values, and where the ramifications in the whole system are thoroughly confusing. Most of the design problems contain a fundamental indeterminacy, which implies that these problems need to be dealt with in a permanent condition of uncertainty and of a situation in which a preferred path only gradually emerges’. The following characteristics are attributed to wicked problems:

- They have no definite formulation.
- They have no stopping rules.
- Their solutions are not true or false, however better or worse.
- There is no immediate and ultimate test of a solution.
- Every solution is a ‘one-shot operation’ since there is no opportunity to learn by trial-and-error, every attempt counts significantly.
- They do not have an enumerable (or an exhaustively describable) set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan.
- Every wicked problem is essentially unique.

- Every wicked problem can be considered as a symptom of another (wicked) problem.
- The causes of wicked problems can be explained in numerous ways; the choice of explanation determines the nature of the problem's resolution.
- (With wicked problems) the planner has no right to be wrong.

On the other hand, spatial planning aims to arrange land use in a way that does not harm its citizens. He or she may assume that change in land use will have no negative impacts on his/her property. In general, this means a playing field in which changes in land use are prevented. Spatial planning is, in this sense, conservative. Moreover, when academic literature is analysed it turns out that the majority of recent articles are oriented on regulatory issues, on a status quo, on a single, specific subject and the subject judge as static (this thesis, chap.3). Additionally, in planning processes problems of the past are often solved instead of problems of the future, in particular when the problem is a long-term or uncertain problem.

The wicked problem of climate adaptation and the way current spatial planning is practiced live at odds. In short, it is difficult to integrate a wicked problem in a system that does not aim for (big) change. And because this is difficult it is also a problem to orientate the content of design on change. This implies the difficulty to capture a long-term, wicked and sometimes uncertain problem in spatial planning or to give it a valuable place.

In order to improve the integration of climate adaptation in spatial planning a new adjusted framework, which allows more room for unpredictable, wicked, dynamic and non-linear processes, is required. To develop such a framework inspiration is found in swarms, because bees, ants, birds and fish are capable of self-organisation, which enables the system to become less vulnerable for (sudden) changes in the environment (Fisher, 2009; Miller, 2010). Swarms perform 'swarm behaviour, which is characterised by high resilience and is very capable to minimise the impacts of uncertainty, complexity and change through developing emergent patterns and structures' (Van Ginneken, 2009)

The proposition in this thesis is therefore to develop a spatial planning framework in which the landscape is seen acting as a swarm in order to easily adapt to unprecedented, unpredictable and unexpected change. This framework forms the core of the thesis.

Swarm Planning Framework

The Swarm Planning Framework consists of the following four components (Fig. 1):

Two Levels of Complexity

As Portugali (2000) describes the city performs self-organisation on two levels: the level of the whole city and the level of individual components. What is described for the system ‘City’ is likely to be true for the system ‘Landscape’ too. When the aim is to perform better adaptation in the landscape it is therefore important to enhance self-organising capacity on both levels. On the level of the whole system this is achieved through implementing strategic interventions, where the system as a whole can be best influenced. These locations can be discovered on the basis of a network analysis. The nodes in the network that are most connected with other nodes and the most important nodes are the most likely places to intervene. On the second level of individual components (e.g., a road, a building, a canal) each component is individually attributed with self-organising capacities. As an example, a house, built at the edge of a lake can be attributed with waterproof elements (wall, door, floor, window) or can be attributed with a base that can float. Every individual component has different properties and therefore needs to be attributed with accompanying capacities. Which of the capacities are most suitable to enhance the self-organising capacity depends also on the environment (e.g., the expected climate impacts. Heat and drought demand other capacities than rain and floods). All components attributed with capacities to increase self-organisation form a self-organising entity, which as a whole developed a higher adaptive capacity. Both levels of complexity together determine the final adaptive capacity of the entire system.

Five Layers

Not every part of the landscape (and the city) changes at a similar pace. A tree, once planted, only changes on the longer term, while an outside café terrace changes more rapidly, especially when the weather is nice. When spatial elements of similar changeability or ‘time-rhythm’ are connected with one spatial layer, the spatial dynamic can be captured and it becomes possible to enhance, predict or facilitate transformations. Each of the five layers is also connected to a spatial scale. Fast change happens often at a smaller scale, while slow changes take place at higher spatial scales. Five layers are distinguished, two more than the three layers of the original layer approach([Frieling et al., 1998): networks, focal points, unplanned space, natural resources and emerging occupation patterns.

Non-linear Processes

For the different spatial elements are specific time-rhythms distinguished. This implies that in the different parts of the Swarm Planning Framework other non-linear processes emerge. Each of these processes contributes to the overall adaptation of the system. *Emerging patterns* and *connectedness* takes predominantly place in networks and between the most intensive nodes. *Tipping points*, defined as the moment the system 'flips' from one state to a new one (Gladwell, 2000), can be spatially identified as the most important nodes in (a combination of) networks. In the unplanned space the impacts of a strategic intervention, a tipping point, can be mitigated. The impact of the intervention on its environment will form *new spatial patterns* through *self-organisation*. The *fitness landscape* is mainly related to natural resources. These resources, such as clean water, nature, food and clean energy often benefit from a stable environment in which natural processes can develop. Changes will happen very slowly in these systems until the system no longer can function properly. At that moment the system jumps to a new state where it can operate in a stable way. The continuous search for this most optimal stable state is called fitness landscape. The emergent occupation patterns develop as a result of self-organisation. This happens more easily when many elements are close together.

Two Planning Processes

In the Framework two ways are described to use the components in a planning process. The first way is 'from small to large'. In this variant the planning starts with an analysis of the slowest changing elements (the natural resources). This forms the basis within which choices can be made for the second slowest layer, the networks. This layer determines subsequently the playing field for the nodes, after which occupation patterns may emerge. Finally, the remaining space is unplanned. The second way to use the Framework in planning is 'on the list of partners'. The analysis of the first layer, the networks, happens in this case first. On the basis of this analysis the most intense and important nodes are determined. These nodes are the most suitable to execute a strategic intervention. The first two layers are also seen as the ones to influence the landscape as a whole and are able to enhance its adaptability at the system level. When the most important nodes are identified and the places for strategic interventions are chosen the space around these nodes is kept unplanned in order to allow the impacts of the intervention emerge freely. The remaining space in the landscape can be used for natural resources. Finally, emerging occupation patterns are identified in the fifth layer and added to the plan.

Both usages of the Framework are valid and will lead to adaptive plans, which enhance the adaptive capacity of the landscape for uncertain future developments.

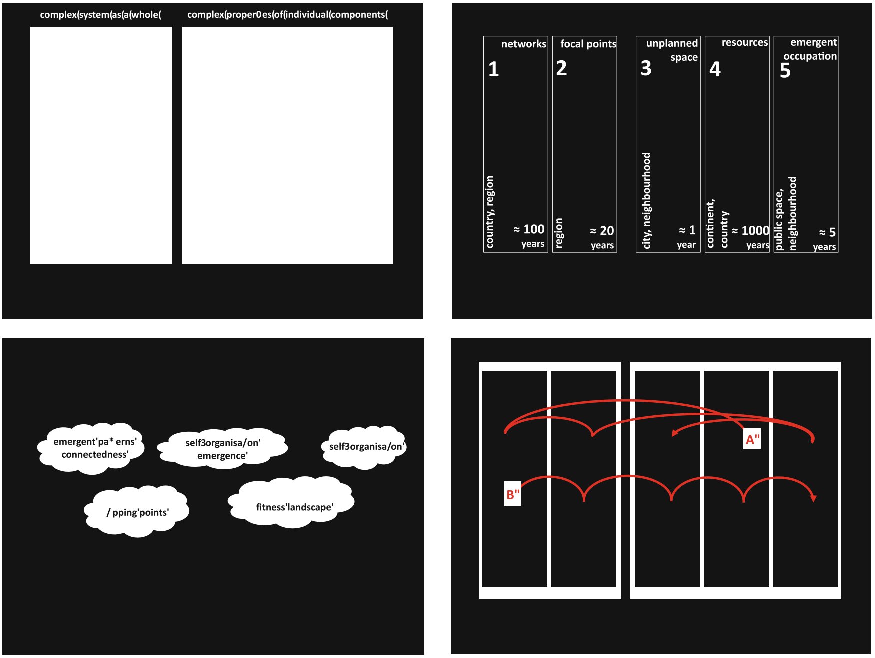

Fig. 1 Four components of the Swarm Planning Framework

The four components together form the Swarm Planning Framework. In Fig. 1 examples of spatial elements are added for each layer. These lists are not complete, nor extensive, but give an indication of the sort elements that belong to each layer.

The Framework is evolved from and tested in pilot designs. During the design of a few pilot designs (Floodable Landscape, Idea Map Groningen en Zero-Fossil Region) parts of the Framework arose. The Framework was subsequently used in the design of other pilots (Peat Colonies, Bendigo).

All design were appraised using criteria for an adaptive landscape: reducing vulnerability of the social, physical and spatial system, reducing of the impact of climate hazards and disasters, the ability to respond to unexpected hazards and whether the plans contain adaptation strategies that were implemented. The results show that the use of the Swarm Planning Framework reduces the vulnerability of landscapes as well as the impact of climate hazards and disasters, better respond to unexpected hazards and contain adaptation strategies.

This thesis consists of ten chapters. The Chaps. 2–9 have been published previously as an academic article, as a book chapter or as part of conference proceedings, and all are (except for Chap. 8) at least double blind peer reviewed. Therefore, each chapter can be read as a stand-alone article. The flipside of this approach is that amongst several articles/chapters there is a slight overlap in content and it sometimes lacks that a logical next chapter evolves from the previous.

In order to overcome these downsides and to increase understanding and readability of the thesis, the chapters will be 'bridged' through short explanatory intermezzos.

Samenvatting

Klimaatadaptatie kan maar moeilijk worden geïntegreerd in de huidige ruimtelijke ordening. Het gevolg daarvan is dat in ruimtelijke plannen slechts in beperkte mate voorzieningen zijn opgenomen die anticiperen op de toekomstige gevolgen van klimaatverandering. Dat betekent dat het landgebruik onvoldoende is voorbereid op deze toekomstige gevolgen. In andere woorden: de adaptieve capaciteit (de aanpasbaarheid) in het landgebruik is niet groot en kan onvoldoende blijken als de gevolgen van klimaatverandering zichtbaar worden.

Dit proefschrift heeft als doel te onderzoeken of er een manier te vinden is die de aanpasbaarheid van het landgebruik kan vergroten door maken van plannen en ontwerpen waardoor het landschap een grotere veerkracht (resilience) verkrijgt en het dus beter bestand is tegen toekomstige gevolgen van klimaatverandering.

De oorzaak voor de moeizame integratie van klimaatadaptatie in de ruimtelijke ordening is gelegen in het verschil in kenmerken van beide.

Klimaatadaptatie wordt gezien als een ongetemd (wicked) probleem (VROM-raad, 2007; Commonwealth of Australia, 2007) of zelfs een super-ongetemd probleem (Lazarus, 2009). Dit soort problemen worden door Rittel en Webber (1973) omschreven als 'een categorie problemen van sociale systemen, die slecht zijn geformuleerd en waar de informatie verwarrend is, waar vele klanten en beslissers met conflicterende waarden zijn en waar de onderdelen van het gehele systeem ernstig verwarrend zijn. De meeste ontwerpproblemen bevatten een fundamentele onbepaaldheid, hetgeen veronderstelt dat met deze problemen moet worden omgegaan in een permanente staat van onzekerheid en in een situatie, waarin een voorkeur zich slechts geleidelijk ontwikkelt'.

De volgende karakteristieken worden aan ongetemde problemen toegedicht:

- Ze kunnen niet in een definitieve vorm geformuleerd worden;
- Ze zijn niet eindig;
- De oplossingen zijn niet waar of onwaar, maar beter of slechter;
- Er is geen directe en ultieme test voor een oplossing;
- Elke oplossing is enig in zijn soort, omdat er geen mogelijkheid is om al doende te leren, dus elke poging is belangrijk;
- Er is geen opsomming (of een uitputtende beschrijving) van een groep mogelijke oplossingen, en er is geen duidelijk omschreven groep toelaatbare activiteiten die kunnen worden opgenomen in het plan;
- Elk ongetemd probleem is in essentie uniek;

- Elk ongetemd probleem kan gezien worden als een symptoom van een ander (ongetemd) probleem;
- De oorzaken van ongetemde problemen kunnen op ontelbare manieren begrepen worden. Hoe de oorzaak van het ongetemde probleem wordt uitgelegd bepaalt het soort oplossing;
- (Met ongetemde problemen) heeft de planner geen reden voor fouten.

Ruimtelijke ordening, aan de andere kant, is er op gericht het ruimtegebruik te regelen op een manier die de burger niet voor verrassingen stelt. De burger mag er van uitgaan dat een veranderend ruimtegebruik geen negatieve gevolgen heeft voor zijn eigendom. In het algemeen betekent dit dat er veel krachten in het spel zijn die verandering van het ruimtegebruik tegengaan. In die zin is de ruimtelijke ordening conservatief. Ook wanneer academische literatuur in ogenschouw wordt genomen blijkt dat verreweg het grootste deel van de recente artikelen zich richten op regelgeving, een status quo, een bepaald en specifiek onderwerp hebben of het onderwerp zien als onveranderlijk en statisch [dit proefschrift, hoofdstuk drie]. Ook in de planvorming is het vaak zo dat een probleem, dat onderkend werd in het verleden, wordt opgelost in plaats van een toekomstig probleem, zeker niet als dat probleem op langere termijn speelt of onzeker is.

Het ongetemde probleem van klimaatadaptatie en de manier waarop de huidige ruimtelijke ordening uitgevoerd wordt leven op gespannen voet. Kort samengevat is het lastig om een ongetemd probleem in een systeem te integreren dat niet gericht is op het toelaten van (grote) veranderingen. En omdat dat lastig is, is het ook een probleem om de inhoud van plannen te richten op verandering. Daarmee wordt het ingewikkeld om een lange termijn, ongetemd en soms onzeker probleem als klimaatadaptatie in ruimtelijke plannen te vatten of een volwaardige plek te bieden. Om de integratie van klimaatadaptatie in de ruimtelijke ordening te verbeteren is er daarmee behoefte aan een nieuw, aangepast raamwerk, dat meer ruimte biedt aan onvoorspelbare, ongetemde, dynamische of niet-lineaire processen. Voor het ontwikkelen van een dergelijk raamwerk is inspiratie gevonden in zwermen, omdat zwermen, zoals bijen, mieren, vogels en vissen in staat zijn tot zelforganisatie, dat het systeem helpt om minder kwetsbaar te worden voor (plotselinge) veranderingen in hun omgeving (Fisher, 2009; Miller, 2010). Zwermen vertonen 'zwermgedrag, dat zich kenmerkt door een hoge mate aan veerkracht en uitermate goed in staat is de gevolgen van onzekerheden, complexiteit en verandering te verminderen door het ontwikkelen van autonoom groeiende patronen en structuren' (Van Ginneken, 2009).

De propositie in dit onderzoek is daarom om een raamwerk voor ruimtelijke plannen te ontwikkelen waarin het landschap gezien wordt functionerend als een zwerm, waarbij het zich makkelijk kan aanpassen aan onverwachte, onvoorspelbare en onvoorzienbare veranderingen. Dit raamwerk vormt de kern van het proefschrift.

Raamwerk voor 'Swarm Planning'

Het Swarm Planning Raamwerk bestaat uit de volgende vier bestanddelen (Fig. 1)

Twee niveaus van complexiteit

Zoals beschreven door Portugali (2000) vindt in de stad zelforganisatie plaats op twee niveaus: op het niveau van de gehele stad en op het niveau van individuele elementen in de stad. Er mag worden aangenomen dat wat Portugali beschrijft voor het systeem 'Stad' ook geldt voor het systeem 'Landschap'. In het creëren van een grotere aanpasbaarheid in het landschap is het dus van belang dat het zelforganiserend vermogen op beide niveaus wordt versterkt. Op het niveau van het gehele landschap wordt dat gedaan door het doen van strategische interventies op plekken waar het systeem als geheel het beste kan worden beïnvloed. Deze plekken kunnen worden gevonden op basis van een netwerkanalyse. De knooppunten in het netwerk die het meest intens verbonden zijn met andere knooppunten en de belangrijkste punten zijn het meest geschikt om een interventie te plegen. Op het tweede niveau, van de individuele componenten (bijvoorbeeld een weg, een gebouw, een kanaal), worden de elementen afzonderlijk 'voorzien' van zelforganiserende eigenschappen. Als voorbeeld kan een woning die aan de rand van het water staat voorzien worden van waterbestendige onderdelen (muur, vloer, raam, deur) of kan de woning voorzien worden van een fundament dat geschikt is om te gaan drijven. Het spreekt voor zich dat elk element specifieke kenmerken heeft en dus ook voorzien moet worden van bijbehorende eigenschappen. Welke eigenschappen het zelforganiserend vermogen het best kan vergroten hangt ook af van de omgeving (ie. het te verwachten soort van impact als gevolg van klimaatverandering. Hitte/droogte stelt andere eisen dan neerslag en overstroming). Alle elementen, voorzien van eigenschappen die het zelforganiserend vermogen vergroten, vormen samen een zelforganiserend geheel dat in zijn totaliteit een grotere aanpasbaarheid heeft verkregen. De beide niveaus van complexiteit tezamen bepalen uiteindelijk de adaptieve capaciteit van het totale systeem.

Vijf lagen

Niet elk onderdeel van het landschap (en de stad) heeft hetzelfde tempo waarin het kan veranderen. Een boom, eenmaal geplant, verandert slechts op de langere termijn, terwijl een caféterras een veel snellere verandering kan ondergaan, zeker als het mooi weer is. Door het toedelen van landschapselementen met vergelijkbare veranderbaarheid of ‘tijd-ritme’, aan eenzelfde ruimtelijke laag wordt de ruimtelijke dynamiek gevangen en wordt het mogelijk om transformaties te bewerkstelligen, te voorspellen of te begeleiden. Elke van de vijf lagen is ook gekoppeld aan een ruimtelijke schaal. Snelle veranderingen vinden vaak plaats op relatief kleine schaal terwijl langzame veranderingen plaatsvinden op hogere schaalniveaus. Er worden vijf lagen onderscheiden, twee meer dan de drie lagen waarvan deze benadering is afgeleid (Frieling et al., 1998): netwerken, knooppunten, ongeplande ruimte, natuurlijke reserves en groeiende occupatie patronen.

Niet lineaire processen

Voor de verschillende ruimtelijke elementen gelden dus verschillende tijdsritmes. Dit impliceert ook dat in de diverse delen van het raamwerk andere niet lineaire processen zullen ontstaan. Elk van de processen draagt bij aan de algehele aanpasbaarheid van het systeem. De groei van *nieuwe patronen* en *verbondenheid* vindt voornamelijk plaats in netwerken en tussen de meest intensieve knooppunten. *Tipping points*, gedefinieerd als het moment waarop een systeem van het ene toestand omschakelt naar een nieuwe toestand (Gladwell, 2000), zijn ruimtelijk vooral terug te vinden als de belangrijkste knooppunten in (een combinatie van) netwerken. In de ongeplande ruimte worden de gevolgen van een strategische interventie, het tipping point, opgevangen. De impact die deze ingreep heeft op zijn omgeving zal als een *zichzelf organiserend* proces nieuwe *ruimtelijke patronen* vormen. Het fitness landschap is vooral gerelateerd aan natuurlijke reserves. Deze natuurlijke bronnen, zoals schoon water, natuur, voedsel en schone energie, zijn vaak gebaat bij een stabiele omgeving, waarin natuurlijke processen zich kunnen voltrekken. Heel langzaam zullen er veranderingen optreden in deze systemen, net zo lang tot het systeem niet langer goed kan functioneren. Op dat moment springt het systeem over naar een nieuwe toestand waarin het weer stabiel kan opereren. Het continue zoeken naar deze optimale stabiele toestand wordt aangeduid met de term fitness landschap. De zichzelf ontwikkelende occupatie patronen tenslotte kunnen zich vormen door zelforganisatie. Dit is vooral mogelijk wanneer er veel elementen in elkaars nabijheid verkeren.

Twee planprocessen

In het raamwerk worden twee processen beschreven waarop de verschillende bestanddelen in de planvorming kunnen worden gebruikt. De eerste manier is ‘van groot naar klein’. In deze variant begint de planvorming met een analyse van die elementen die het traagst kunnen veranderen (de natuurlijke reserves). Dit vormt de basis waarbinnen ruimtelijke keuzes kunnen worden gemaakt voor de op één na traagste laag, de netwerken. Deze laag bepaalt vervolgens het speelveld voor de knooppunten, waarna nieuwe occupatiepatronen zich kunnen ontwikkelen en er tenslotte ruimte overblijft die ongepland kan blijven. De tweede manier om het raamwerk in de planvorming te gebruiken is 'op het rijtje af'. Hier wordt gestart met een analyse van de eerste laag, de netwerken. Vervolgens wordt op basis van deze analyse bepaald welke knooppunten de meest intense en belangrijkste zijn. Deze knooppunten zijn geschikt voor een strategische interventie. Deze eerste twee lagen worden bovendien gezien als degenen die het landschap als geheel kunnen beïnvloeden en de aanpasbaarheid op systeemniveau kunnen vergroten. Wanneer de belangrijkste knooppunten bepaald zijn en de plek(ken) voor een strategische interventie gekozen zijn, kan de ruimte rondom deze punten als ongeplande ruimte vrijgehouden worden. Hier wordt de ruimte gevonden waar de impact van de interventie zich vrij kan ontwikkelen. Dit laat vervolgens ruimte over in het landschap die ingevuld kan worden voor het produceren en veiligstellen van natuurlijke reserves. Tenslotte worden in de vijfde laag de nieuwe occupatiepatronen geïdentificeerd en toegevoegd aan het plan. Beide werkwijzen zijn valide en zullen leiden tot plannen waarin de aanpasbaarheid van het landschap aan onzekere toekomstige ontwikkelingen wordt vergroot.

De vier bestanddelen tezamen vormen het Swarm Planning Raamwerk. In Fig. 2 zijn voor elke laag voorbeelden van ruimtelijke elementen toegevoegd. Deze lijstjes

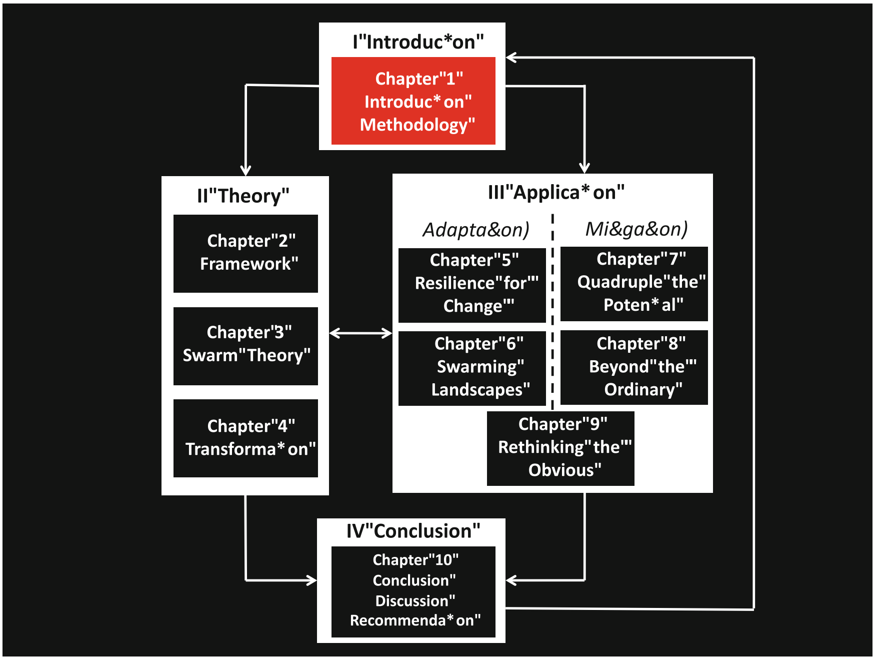

Fig. 2 The Swarm Planning Framework

zijn niet compleet en uitputtend, maar geven een indicatie van het soort element dat behoort tot de betreffende laag. Het raamwerk is ontstaan uit en getest in pilot ontwerpen. Gedeeltelijk zijn tijdens het ontwerpen van een aantal van de pilots (Floodable Landscape, Idea Map Groningen en Zero-Fossil Region) onderdelen van het raamwerk gevormd. Vervolgens is het raamwerk gebruikt bij het ontwerpen van andere pilots (Peat Colonies, Bendigo). De ontwerpen zijn vervolgens getoetst aan criteria die een aanpasbaar landschap beschrijven: verminderen van de kwetsbaarheid van het sociale, fysieke en ruimtelijke systeem, vermindering van de ernst van klimaatrisico's en rampen, het vermogen om in te spelen op onverwachte risico's en bevatten de plannen adaptatie maatregelen die kunnen worden geïmplementeerd. De resultaten van de pilot ontwerpen laten zien dat het gebruik van het Swarm Planning Raamwerk de kwetsbaarheid van landschappen vermindert, de ernst van klimaatrisico's en rampen vermindert, beter kunnen inspelen op onverwachte risico's en adaptatie strategieën bevatten.

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Chapter 1
Introduction, Methodology, Limitations

1.1 Introduction

The current status and significance of climate adaptation and its connections with spatial planning can be interpreted taking different perspectives. Scientific conferences, research programmes and writings are subsequently used as lenses of observation.

A selection of recent and future conferences in different scientific fields shows a strong focus on the specific topic. Whilst this is logical and probably inevitable, the flipside is that links with other fields are underdeveloped and the integration of different subjects is not much practiced. This can be illustrated through analysis of a couple of recent scientific, global, conferences.

The majority of scientific papers that were published in the proceedings of the first International Climate Change Adaptation Conference, held in 2010 (http://www.nccarf.edu.au/conference2010) in the Gold Coast, Australia, focuses on thematic and process oriented topics, with the top-four issues being Governance, Agriculture, Ecology and the Coast [own calculations]. Only two out of 209 oral presentations addressed integrated planning and design (Mack et al. 2010; Roggema 2010).

The second edition of this conference, held in Tuscon in 2012 (http://www.adaptation.arizona.edu/adaptation2012), focuses on similar priority themes: regional studies about the most vulnerable people, climate impact science, communication, building adaptive capacity, examples and cost benefits, funding, tools, evaluation and adapting under four degrees warming. Spatial planning and/or design are conspicuously absent.

What is true for adaptation conferences is also valid for other fields of research. The resilience research community, represented at the Resilience 2011 conference (www.resilience2011.org), did not address spatial planning nor climate adaptation. In reverse, the spatial planning community, convened at the World Planning Schools Congress (www.wpsc2011.com.au), save two design-oriented papers (March and Holland 2011; Roggema and van den Dobbelsteen 2011), addressed climate adaptation only in regards to specific hazards or coastal issues.

R. Roggema, *Swarm Planning*, Springer Theses, DOI: 10.1007/978-94-007-7152-9_1,

Taking two research programmes as representatives for the connections between spatial planning and climate adaptation (ESPACE, www.espace project.org and CCSP, www.climatechangesspatialplanning.nl), both programmes hardly host projects that are oriented at making/designing spatial plans, despite the fact they specifically aim to link spatial planning with climate adaptation. Most of the CCSP-projects that look into the spatial planning topic do so by developing tools to facilitate spatial planning and helping 'them' (e.g. the spatial planners) to improve climate adaptation in their plans (De Pater et al. 2011).

A broad and growing body of literature with adaptation to climate change as main topic has been released (see for example: Godschalk and Brower 1989; Godschalk et al. 1999; Berke 1992, 1997; Brower and Schwab 1994, 2002; Beatley 1994, 2009). Nearly all of these writings address a very specific theme (e.g. coastal management, biodiversity, disasters) or are specifically focused on mitigation (Newman and Boyer 2009). Moreover, it is illustrative that '*the Earthscan reader on Adaptation to Climate Change*' (Schipper and Burton 2009) has not included a chapter on spatial planning. One other major work on planning and climate change, '*Planning for Climate Change*' (Davoudi et al. 2010) focuses also mainly on processes, policies and specific topics, such as transport. Only few chapters in this book cover *spatial* planning, urban form or urban design. With the exception of Elisabeth Wilson (2009), the parts that do cover these issues are oriented on cities and urban areas.

This analysis is underpinned by the survey of Carter and Sherrif (2011), who conclude that adaptation is only just been acknowledged as an important element for cities and urban areas, the limited uptake of adaptation responses in spatial planning must change, adaptation should be seen as a constituent element of governing and designing urban areas, and the role of spatial planning in delivering adaptation responses must be strengthened.

Climate adaptation framed from a spatial planning perspective emphasises the role of spatial planning itself (Roggema 2009a). In several publications, it is acknowledged that spatial planning can (and must) play a vital role 'in every aspect of adaptation to climate change impacts' (Blanco and Alberti 2009) and spatial planning is seen to 'play a part in mitigation and adaptation efforts' because 'the nature and framing of spatial planning is changing' as a result of the 'recognition of the complexity, uncertainty and irreversibility demonstrated by climate science' (Davoudi et al. 2010, p. 14).

In the extension of the above, the main focus of my research is on the way climate adaptation can be better incorporated in spatial planning. The view I have on this matter is that to present climate change as a threat, setting aside whether the worsening of the problem is real or just a perception, paralyses action. It is more productive to frame the problem positively. This requires acceptance of the assumptions voiced by the climate science community and using this information to inform spatial planning community in a way that offers a fundamentally new way to incorporate climate adaptation. Instead of presenting the uncertainties surrounding climate change, a planning approach needs to be developed, which spatial planners experience as a part of their spatial planning discourse.

The language, the elements and topics need to be linked with the spatial reality ‘out there’ and the way spatial planners are used to design their plans.

In this chapter climate change and climate adaptation, spatial planning, complexity and time horizons are briefly introduced. Secondly, the problem statement, objective, hypothesis and research questions of the research are formulated. The chapter ends with an exploration on key concepts that emerged over time during the execution of the research.

1.2 Climate Change

It is not the aim of this research to contribute to scientific research and/or debate regarding climate change. As mentioned above, the starting point for the research is the assumption that global climate is changing, as stated in many scientific records (as main source: IPCC 2007) and, according to several publications, at an increasing pace (Tin 2008; Richardson et al. 2009; PBL et al. 2009; Sommerkorn and Hassol 2009; NASA/Goddard Space Flight Center 2011).

Secondly, due to the extended effect of global warming, change will continue for centuries (Fig. 1.1), even if we stop to emit carbon dioxide today. After CO_2 emissions are reduced and atmospheric concentrations stabilize, surface air temperature continues to rise by a few tenths of a degree per century for a century or more, thermal expansion of the ocean continues long after CO_2 emissions have been reduced, and melting of ice sheets continues to contribute to sea-level rise for many centuries (IPCC 2001).

The changes in climate are found to be non-linear, meaning that the estimated fluent curve of change, much used in climate science, needs to be re-adjusted in a shape that looks more like a staircase (Fig. 1.2) (Jones 2010, 2011).

It may be concluded that the effects of climate change will stay with us for an extended period of time and the changes will take place in ‘jumps’. Therefore, adaptation is needed and it needs to be able to deal with the step changes as illustrated above.

1.3 Climate Adaptation

Current adaptation policies are mainly focussing on risk assessments, building adaptive capacity (of organisations, people), and financial arrangements. Many adaptation measures are taken in separated policy fields, such as coastal management, ecology, infrastructure, water management or agriculture. The question therefore is how climate adaptation is framed from a spatial planning perspective and, is it framed from a spatial planning perspective? Several scholars have published about the framing of climate adaptation. These theories all take climate adaptation as the starting point and frame ‘the rest’ from that point of view.

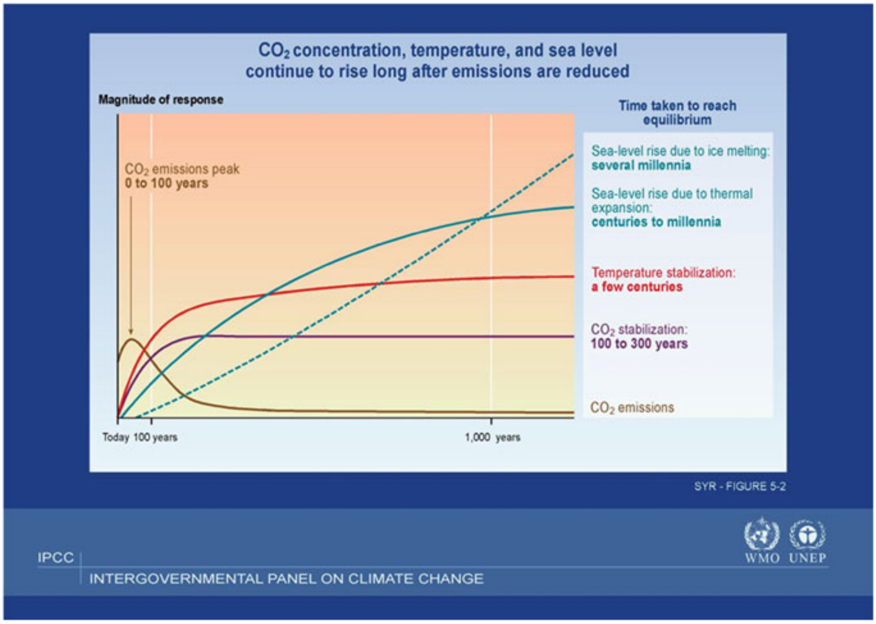

Fig. 1.1 Inertia of Earth's components in response to reduced CO_2 concentration (IPCC 2001)

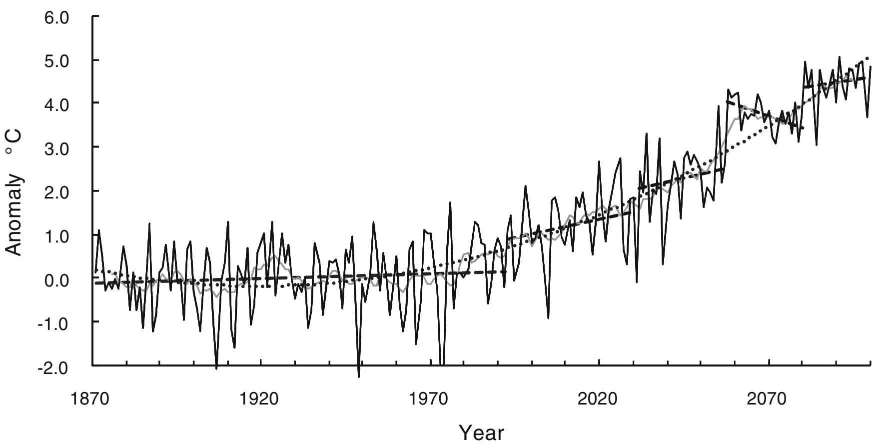

Fig. 1.2 Step and trend analysis, based on dummy data, illustrating one of many analyses showing the 'staircase' behaviour of climate change (Jones 2011)

Horstmann (2008), for instance describes the transition in the framing of adaptation from climate science driven, via vulnerability assessments towards adaptive capacity, which is defined as *"the whole of capabilities, resources and institutions of a country or region to implement effective adaptation measures"* (Parry et al. 2007), also implying a shift from a focus on the technical towards social policy measures. The definition of adaptation by the IPCC as ‘adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities’ (IPCC 2007) raises three questions: adapt to what, who and what should adapt, and how to adapt? These questions are in general answered with: we need to adapt to climatic change (to what), the system, e.g. ecological, economic, social or political systems should adapt (who and what) and we could adapt autonomous/reactive or in a planned way (how to) (Smit et al. 2000; Horstmann 2008). Spatial planning is not a topic that appears very often in the framing schemes. Dessai and Hulme (2004) define adaptation policy sitting on the turning point between a bottom-up and top-down approach (Fig. 1.3), respectively referring to social (with a focus on past and present) and physical (with a predominant focus on the future) vulnerability, but leaving out the spatial domain apart from planning horizons.

Both (Horstmann, and Dessai and Hulme) place social, institutional aspects in the local short-term part and technical–physical aspects in the long-term global part of the scheme. The framing of climate adaptation measures in Fuenfgeld and McEvoy (2011) also places technical measures to the higher spatial scale and social-behavioural measures to the local-individual scale (Fig. 1.4), but both groups of measures are proposed for short and longer terms, with a focus for the social measures on the shorter period. Regulatory and financial measures, as well as capacity building measures are added to the spectrum of adaptation measures, applicable nearly always at every scale. Spatial planning measures are, here also, nearly absent, a planning is defined here as ‘the collective of processes and steps undertaken to address the impacts of climate change’, which is not a definition of planning in a spatial manner.

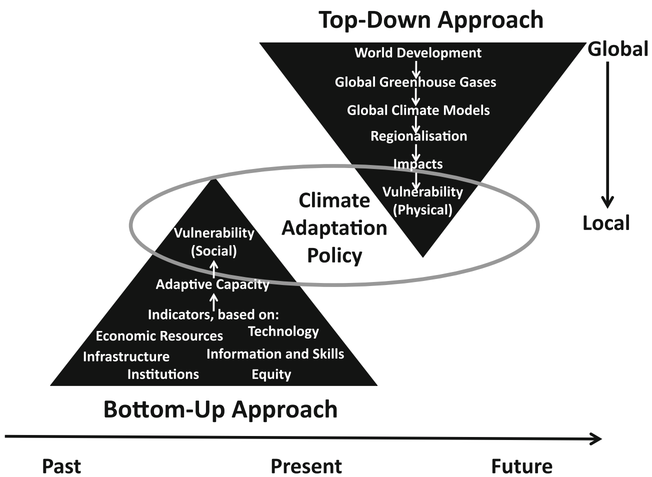

Fig. 1.3 Adaptation policy in between bottom-up and top-down (after: Dessai and Hulme 2004)

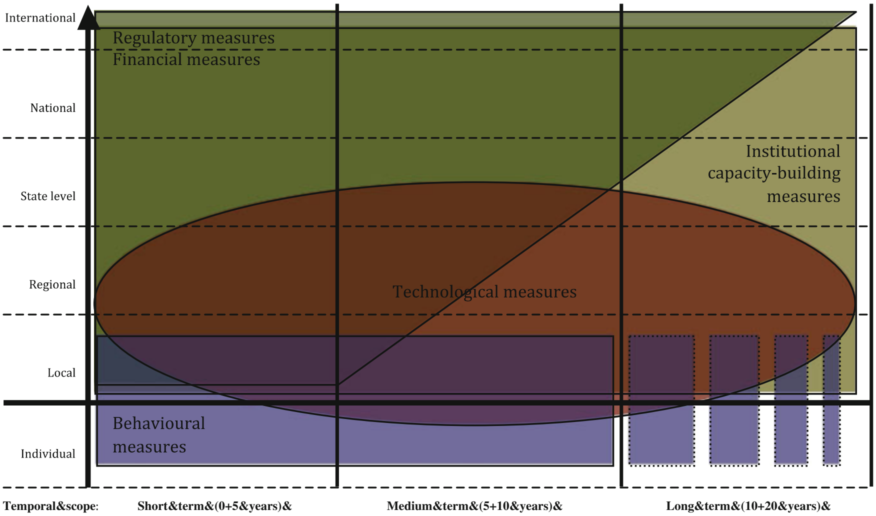

Fig. 1.4 Typology of adaptation measures (Fuenfgeld and McEvoy 2011)

Only very few connections can be found with spatial planning. Following Smit et al. (2000), Horstmann uses spatial scales to identify the tension between the scale of operation of governance and institutions, and climate trends, but this is presented as a question mark in Horstmann's figure (Horstmann 2008). However, when this scheme is reconfigured (Fig. 1.5) and time scales and spatial scales are used as both axes, the long-term and large scale part in the right top corner is where most of the technical, traditional climate change research takes place.

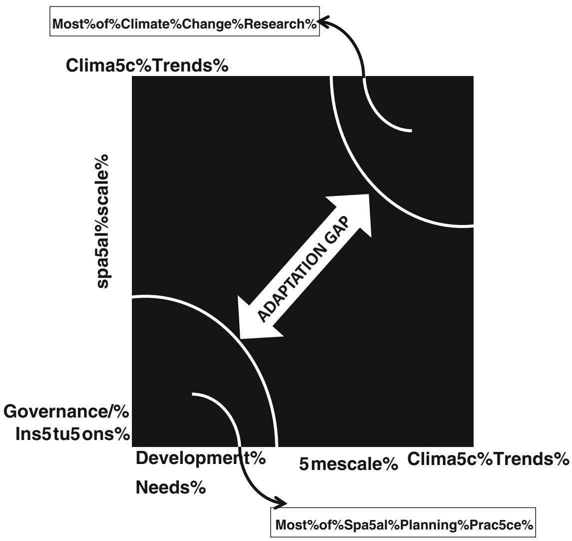

Fig. 1.5 The 'adaptation gap' between the spatial and time scale of development needs (shorter time scale), governance and institutional focus (smaller scale) and climatic trends (longer term, larger scale) (after and adapted from Horstmann 2008)

The left bottom corner represents the shorter term and local scale. Most of the spatial planning practice can be found here. The space in between illustrates the, what can be called the 'adaptation gap' between climate trends and most of the research and the application in practical spatial planning.

This adaptation gap is the space where the 'to what, who, what, why and how to' of adaptation needs to be answered (Fig. 1.6). The question is however, how to do this. It is clear that the time-space scales, currently isolated in opposite corners of the scheme need to be brought closer together. In order to so we need to go beyond posing the questions or to answer each individual question. Search for a unifying concept that is able to connect both worlds, by making use of characteristics found in both parts.

Is spatial planning a minor issue in climate adaptation literature, climate adaptation, in reverse, is not an important subject in spatial planning literature. From a spatial planning perspective, this gap needs to be filled with a framework that is capable of including climate change research outcomes of the 'longer-term, higher scale' sort and is able to extend its applicability to multiple time- and

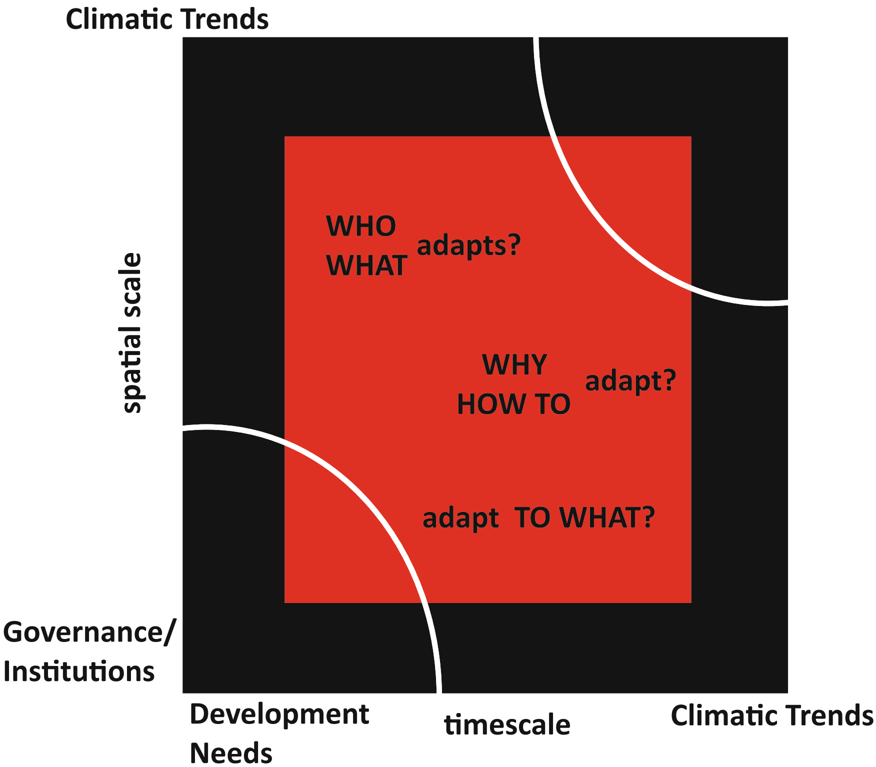

Fig. 1.6 The 'to what, who, what, why and how' of adaptation positioned between large-scale long-term climate trends and short-term local scale (adapted from and elaborated on Smit et al. (2000) and Horstmann (2008))

spatial scales. The question how climate adaptation can become a valuable part in spatial planning is in this context more important than the question what best adaptation is.

1.4 Spatial Planning

One of the main reasons for the limited uptake of adaptation in spatial planning is that spatial planning theory and practice (see Chap. 3: Roggema 2012b) focuses on the well-defined problems of the sort: we have a problem, we define a methodology, we conduct the research, we define/develop the solution (this part is often left out in many research papers) and we conclude. The approach in spatial planning practice is slightly different: there is a societal demand/problem, we have a quantitative programme, we define the goal (e.g. to realise the programme), we develop a plan that realises that programme and we conclude (the programme will be realised *because* of the plan).

Many spatial planning frameworks are not equipped to deal with uncertainty in the programme or in the problem. Climate change adaptation is seen as a wicked (Rittel and Webber 1973) problem (O'Brien et al. 2008; VROM-raad 2007; Commonwealth of Australia 2007; Lazarus 2009), which cannot be well defined nor dealt with in the 'problem, method, solution, conclusion' way.

Climate adaptation may be seen as a wicked problem, the original use of the term wicked problems related to most of the problems addressed by designers. Rittel and Webber describe design problems as 'a class of social system problems, which are ill-formulated, where the information is confusing, where there are many clients and decision-makers with conflicting values, and where the ramifications in the whole system are thoroughly confusing. Most of the design problems contain a fundamental indeterminacy, which implies that these problems need to be dealt with in a permanent condition of uncertainty and of a situation in which a preferred path only gradually emerges' (Rittel and Webber 1973). This opinion is found opposite of the rational problem solving approach. De Jonge (2009) links design problems, as wicked problems, with the Reflexive Practice Approach (Schön 1983) and unstructured problems, which are dealt with through a learning strategy (Hirschemöller and Hoppe 1995). In dealing with unstructured problems, for which both the consensus on relevant norms and values as well as the certainty about relevant knowledge is absent, participants present information on the issue, become aware of the multiple aspects of the problem and are enabled to reframe their conception of the problem, and are able to bring new visions and opportunities for solving the problem within reach (De Jonge 2009). The Reflexive Practice Approach is seen as a reflexive conversation with the situation, with oneself and with many different people involved in the (design) process. This approach is in contrast with the Rational Problem Solving Approach (Schön 1987). It may be concluded that a design process, dealing with design, wicked and unstructured problems (e.g. amongst others climate adaptation), may profit from methodologies that are reflexive: in which a conversation is possible between and amongst the designers and participants in the process.

The planning framework as it is still in use in many practices, and belonging to the Rational Problem Solving schools, needs therefore to be adjusted, assuming that there is a benefit in using spatial planning as a (co-)solving carrier for climate adaptation. The facts that many climate impacts happen or have effect in the spatial domain, they impose changes in the way cities and landscapes are able to function and threaten and influence people's lives, give reason to use spatial planning in this sense. This adjusted spatial planning framework needs to be able to deal with unstructured, wicked design problems: it needs to deal with different time dimensions, it needs to be prepared for unexpected and unpredicted impacts, and it needs to be capable of incorporating the spatial consequences of uncertainty. This is a fundamental different framework compared with the current one. We cannot solve wicked problems with frameworks that were used to solve structured problems in a Technical Rational way. Even 'repairing' the existing framework to face fundamental different problems does not function because this repaired existing framework will solve problems in the way it always has done. Muddling through, as Lindblom (1959) defined the way of planning that only looks at the small difference of the problem compared to the former problem, in which policy makers easily tend to avoid interpreting problems as unstructured, whilst maintaining, or gradually change, limited dimensions and targets that do not represent the 'real world', using linear trend extrapolations (Vanstiphout 2000), and thus overlooking or denying relevant elements of the problem, is no option.

1.5 Complexity and Time Horizons

The character of the problem needs to be represented in the new planning framework. If climate adaptation is wicked, if it occurs over different time horizons, it will not work if this problem is tackled using a framework that is suited for solving tame problems with a fixed time horizon.

One way out of this is to adjust the planning framework introducing multiple time dimensions and create space for the system to operate as a complex, self-organising system, because this allows for 'treatment' of the wicked problem. A wicked problem requires a solution which is constantly self-organising the solutions, the system to finds its best shape possible to deal with the form the wicked problem at a certain moment appears in, and needs to be able to reorganise itself immediately after the wicked problem has redefined itself the next moment.

Therefore, Complexity Theory, dealing with complex adaptive systems and self-organisation, is found useful (Chap. 3). A complex system performs behaviour allowing it to change towards a state of higher adaptive capacity, being the mountaintops in the fitness landscape (Fig. 1.7) (Mitchell Waldrop 1992; Langton et al. 1992). Amongst the concepts found relevant are self-organisation, bifurcation

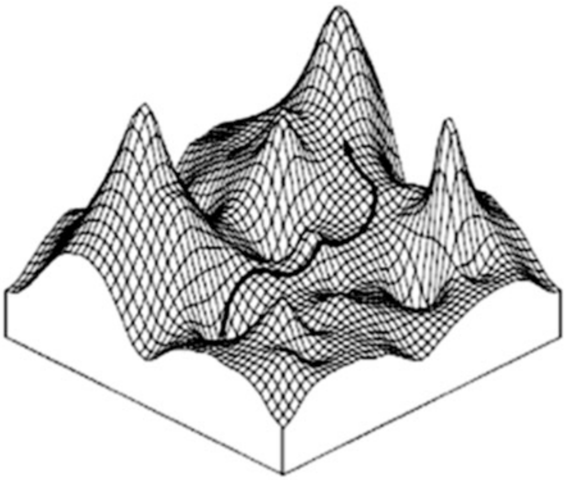

Fig. 1.7 Complex system moving through the fitness landscape towards the mountaintop of higher adaptive capacity (Cohen and Stewart 1994)

and tipping points and transformation in times of crisis (e.g. the lowest parts of the fitness landscape) of systems towards a state of higher adaptive capacity.

Moreover, multiple time dimensions can be introduced learning from the Layer approach, which links different paces of change to different layers in the spatial domain.

1.6 Problem Statement, Objective, Point of Departure and Research Questions

Given the contexts sketched before, the major question in the research is how a spatial planning framework or approach can be developed to enable spatial systems to reach a higher adaptive capacity and to improve their capability to adapt.

Adaptive capacity is defined as "*the ability to* design *and implement effective adaptation strategies, or to react to evolving hazards and stresses so as to reduce the likelihood of the occurrence and/or the magnitude of harmful outcomes resulting from climate-related hazards*" (Brooks et al. 2005). In addition, the Fourth Assessment report of the IPCC defines adaptive capacity as *"the whole of capabilities, resources and institutions of a country or region to implement effective adaptation measures"* (Parry et al. 2007). Following these definitions, a high adaptive capacity is defined here as '**A country or region is well equipped to design and implement effective adaptation strategies and measures**'.

IPCC defines adaptation as the *"initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects. Various types of adaptation exist, e.g. anticipatory and reactive, private and public, and autonomous and planned. Examples are raising river or coastal* *dikes, the substitution of more temperature-shock resistant plants for sensitive ones,* etc.*"* (Parry et al. 2007). Given the uncertainty of future climate change, adaptation needs also to include unexpected or unprecedented climate change effects. Hence, good adaptation is defined here as '**The capability of human and natural systems to reduce their vulnerability against actual, expected or unprecedented climate change effects**'.

Problem Statement

Current spatial planning theory and practice do not enhance the development of cities and landscapes with a high adaptive capacity. Hence, these cities and landscapes do not easily adapt to the impacts of climate change. This is caused by the fact that current spatial planning theory and practice does not have a planning framework available that can include wicked problems and multiple time dimensions.

Objective

To develop a spatial planning framework that can accommodate (wicked) characteristics of climate adaptation, thereby enabling the design of cities and landscapes that can adapt more easily to climate change.

Point of Departure

In the majority of the research the hypothesis is derived from problem statement and the objective (namely to solve the problem). In general, the hypothesis forms the potential solution of the problem statement. In the research this hypothesis needs to be tested whether it forms a plausible solution to the problem or not. A hypothetical hypothesis to the problem statement and objective as formulated above would read as follows:

> A planning framework or approach, in which wicked problems and multiple time dimensions can be included, allows for the planning and design of cities and landscapes with a high adaptive capacity. These landscapes are better able to adapt to the impacts of climate change.

However, in this case the objective to 'develop a spatial planning framework' in which the wicked problem of climate change can be incorporated, thus making it possible to create and design landscapes with a high adaptive capacity, places us for difficulties as this hypothesis cannot be satisfactory tested. The aim is to develop a framework and this framework can be brilliant or useless, but the bottom line is that it has been developed. It is obvious that this on its own is not enough to meet the objective and/or solve the problem that currently there is an absence of a planning framework that is capable of including the wicked problem of climate change. Not any framework that would have been designed in the course of this research would satisfy.

Therefore, to overcome the difficulty of defining a hypothesis, several qualities of the spatial planning framework are defined first as the Point of Departure of the research. These qualities can be researched independently and for every quality a separate research question can be defined. The results of these separated parts then are used to assemble the spatial planning framework, which as a whole forms the response to the problem statement. The following qualities of a spatial planning framework are distinguished:

- It needs to bridge the gap between spatial planning practice and climate adaptation (leading to research question (RQ-A);
- It needs to unify the time gap between short-term planning practice and long-term climate change (RQ-B);
- It needs to provide a method that deals with wicked problems (RQ-C);
- It needs to enhance the possibility of system change (RQ-D);
- It needs to support the development of resilient regions (RQ-E);
- It needs to allow for the design of low-carbon and renewable energy plans (RQ-F and RQ-G);
- It needs to allow for the design of climate adaptive plans (RQ-H).

For each of these qualities specific research questions are formulated.

Research Questions

In order to research the hypothesis two primary research questions (PRQ) have been addressed:

1. Can a spatial planning framework be developed, which is capable to deal with the (wicked) characteristics of climate adaptation?
2. Does this alternative spatial panning framework produce designs for adaptive cities and landscapes?

These main questions are subdivided into secondary research questions (SRQs). The first primary research question, focusing on the spatial planning framework, is subdivided in the following secondary questions:

A. How can the 'adaptation gap', between tame spatial planning practice and the wicked character of climate adaptation be closed? This question is addressed in Chap. 2. Topics such as complex adaptive systems (CAS), the Layer approach, spatial planning and climate adaptation have been researched in the form of a literature review. The findings from that review have been validated in the case study research[1] of Groningen province
B. What kind of planning framework is capable of unifying the time gap, between short-term oriented spatial planning and long-term oriented climate adaptation? This question, also addressed in Chap. 2, emphasises the development of the spatial planning framework, through combining components of the layer

[1] In general, case studies can be used as a research approach when 'how' and 'why' questions are being posed, when the investigator has little control over events and when the focus is on a contemporary phenomenon within some real-life context (Yin 2003). Case studies are conducted in an explanatory, descriptive, exploratory, illustrative way or as a meta-evaluation.

approach, spatial planning elements and Complex Adaptive Systems (CAS). The spatial planning framework has subsequently been validated in the case study research for the Groningen area;

C. What is a suitable planning method/approach for dealing with wicked problems, such as climate adaptation? This question is addressed in Chap. 3. The literature review examined recent and current spatial planning paradigms as well as complexity theory and its applications in cities. On the basis of these reviews the Swarm Planning Theory has been developed, which brings together these theoretical complexity concepts in a spatial planning approach. The theory has subsequently been tested through participatory action research,[2] within the case study research for a bushfire resilient landscape in Bendigo, Australia;

D. What is the most suitable pathway to achieve a fundamental shift towards a spatial system, which is capable of increasing resilience? In Chap. 4, literature review has been conducted on transition and transformation. The outcomes of these reviews were used to elaborate the concept of transformation, through participative action research and appreciative inquiry.[3]

The second Primary Research Question, focusing on the application of the Swarm Planning theory, has been subdivided in the following secondary research questions:

E. How can the resilience of a region be improved, in order to support this region to deal with climate change? This question is the subject of Chaps. 5–6. In these chapter literature review has been conducted on resilience, Complex Adaptive Systems and climate change (Chap. 7) and uncertainty, swarms and Complex Systems (Chap. 6). Through Participative Action Research two case

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[2] The characteristics of Action Research are defined as: Critical collaborative enquiry by reflective practitioners, who are accountable in making results of their enquiry public, self-evaluative of their practice, and engaged in participative problem solving and continuing professional development (Zuber-Skerritt 1992). In Action Research (Winter 1989) **people reflect** on issues and processes, and thoughts are conceptualised in **dialogue**. Focal elements are **unstable**, because these are most likely to **create change**. Participants in Action Research are co-researchers. Each person's ideas are **equally significant**, as Action Research strives to avoid the skewing of credibility stemming from the prior status of an idea-holder. In Action Research cycles of posing questions, gathering data, reflecting and deciding on the course can be used, which allow for learning and feedback during the process. The course of the research can be adjusted depending on the reflections (Ferrance 2000). Participative Action Research (PAR) is a method where the primary goal is to create an environment and process where context-bound knowledge emerges to develop **'local theory'** that is understandable and actionable. The role of the researcher in this case is one of many 'co-learners'—not an expert, but a **'co-producer of learning'**.

[3] Appreciative Inquiry (Srivastva and Cooperrider 1999; Cooperrider and Whitney 2005; Cooperrider 2008) consciously creates **common images** of a **desired future** situation. The starting point is looking for and **making use of the strengths** of the individuals and of the group. The methodology is based on four 'powers': looking for success, imagining a commonly desired future, language and **story telling** and translating images into **concrete action.**

study areas have been researched Groningen province (Roggema 2008a, 2009c) and several individual projects within (Chap. 5) and the Floodable Landscape of the Eemsdelta region (Chap. 6);

F. How can spatial design be informed to reach higher mitigation goals? This question has been researched through case study research in three cases in Chap. 7: on the regional level in Northern Netherlands/Groningen province, on the neighbourhood scale in Almere Municipality and on the building level in Mildura, Australia. In each of the case studies the methodology of Research by Design[4] has been applied in the form of developing Energy Potential Maps, Energy Mix maps and Regional and Local designs;
G. How can a full renewable energy supply be designed? The literature review conducted to research this question, addressed in Chap. 8, examined the connections between Sustainable Energy and Spatial Planning (Roggema et al. 2006; Roggema 2009b)as well as all Energy potential studies recently being carried out. The methods used to link energy and spatial fields of research are trans-disciplinary research, participatory action research and appreciative inquiry;
H. How can Swarm Planning Theory be applied to the design of climate adaptive plans? This question, addressed in Chap. 9, has been researched through literature review of focuses on planning theory, the layer approach and complexity. More specifically, the Five Layer Approach, as developed in Chap. 2, has been elaborated and applied in case study research of the Zero Carbon landscape and the Carbon-Capture landscapes. The methodologies followed in this research were participatory action research, trans-disciplinary Research[5] and appreciative inquiry.

A summary of the research questions and applied research methodologies is given in Table 1.1.

The first set of research questions focus on building the spatial planning framework in which climate adaptation has a prominent and logical position. The proof of the pudding is in the eating, meaning that the application of the Swarm Planning framework in concrete design questions needs to prove its functionality. These applications take place in conducting the second set of research questions, which all use the framework for a very different variety of subjects. The bottom

4 Research by Design is used when both context and object of the design are variable. When both object and context are unidentified this means that the exploration of an agenda is the focus of the process and design is used to discover or unfold the agenda. Once the agenda is discovered the focus comes on the exploration of type (characteristics of the object) and identity (genius loci) (Frieling, in: De Jong and van der Voordt 2005, p. 493).

5 Trans-disciplinary (Action) Research, T(A)R (www.transdisciplinarity.ch) complements applied research in problem fields characterised by **complexity and uncertainty**: "There is a need for TR when knowledge about a socially relevant problem field is **uncertain**, when the concrete nature of problems **is disputed**, and when there is a **great deal at stake** for those concerned by problems and involved in dealing with them" (Pohl and Hirsch Hadorn 2006, p. 20). Examples of such problem fields are migration, violence, health, poverty, global environmental change and cultural transformation processes, among others.

Table 1.1 Overview over research questions

Primary research question (PRQ)	Secondary research question (SRQ's)	Applied research methodologies	Chapter
Can a spatial planning framework be developed, which is capable to deal with the (wicked) characteristics of climate adaptation?	A. How can the 'adaptation gap', between tame spatial planning practice and the wicked character of climate adaptation be closed?	Literature review validation in case study	Chap. 2
	B. What kind of planning framework is capable of unifying the time gap, between short-term oriented spatial planning and long-term oriented climate adaptation?	Development of the framework Validation in a case study	
	C. What is a suitable planning method/ approach for dealing with wicked problems, such as climate adaptation?	Literature review Development of swarm planning theory validation in a case study action research	Chap. 3
	D. What is the most suitable pathway to achieve a fundamental shift towards a spatial system, which is capable of increasing resilience?	Literature Review Participative action research appreciative inquiry	Chap. 4
Does an alternative spatial panning framework produce designs for adaptive cities and landscapes?	E. How can the resilience of a region be improved, in order to support this region to deal with climate change?	Literature study Case study research participative action research	Chap. 5
		Literature study Case study research	Chap. 6
	F. How can spatial design be informed to reach higher mitigation goals?	Case study research Research by design	Chap. 7
	G. How can a full renewable energy supply be designed?	Literature review Case study research Trans-disciplinary research, participatory action research, appreciative inquiry	Chap. 8
	H. How can the swarm planning theory be applied to the design of climate adaptive plans?	Literature review (planning) Elaboration of the five layer approach Case study research participatory action research, trans-disciplinary research, appreciative inquiry	Chap. 9

line in judging the quality and functionality of the framework is to which extent it delivers designs for cities and landscapes with a high adaptive capacity. These cities and landscapes are capable of adapting to climate change, better than the ones with a lower adaptive capacity. Therefore, judgement of the designs delivered through using (parts of) the Swarm Planning framework, needs to be executed through application of criteria derived form the definitions of adaptive capacity and adaptation as cited before. In extension of these definitions, criteria can be formulated to judge the adaptive capacity of and the capability to adapt of designs for cities and landscapes. These criteria will be used to validate the spatial planning framework as developed in this research.

1. Reduce social, physical, but also spatial, vulnerability to the impacts of climate change. Can the social system, the physical system and the spatial system adjust themselves or respond to a hazard/disaster? Are the spatial elements in the city or the landscape able to change if necessary? Is there space available in the city or landscape where social and physical systems can find the flexibility to change (expand, shrink)?
2. Reduce the likelihood of occurrence or magnitude of climate hazards and disasters. Does the design for the city-landscape contain protection and/or back-up structures and elements? Is the city, landscape capable of changing in a short period to (partly) another use?
3. Be flexible to react to evolving hazards, which might result from actual, expected and unprecedented climate change. Does the design for the city and landscape allow for the flexibility to fill up spaces with new uses under changing climate circumstances, even if they are unprecedented?
4. Contain and implement adaptation strategies. Are the identified adaptation strategies implemented in the design for the city and landscapes?

The plans and designs that are researched in this thesis will be examined against these criteria in the conclusion chapter.

1.7 Methodology

As mentioned before, the type of problems named wicked or unstructured require methodologies in which opinions and perceptions in interaction with each other can change and be adapted. These methodologies, commonly shared under Reflexive Practice Approach allow the problem to change over time and participants to adjust their opinions and contribute new and alternative solutions.

The question to develop a planning approach in which climate adaptation can be included, requires methodologies that are open for and/or consist of the ability to deal with future uncertainty (of climate effects), involve systems thinking (human and natural systems) and are value-based (design, different perspectives).

There is not one single methodology that can be used and meets these requirements. All methods and approaches that were used to research the secondary research questions, as outlined before, fit under the umbrella of Qualitative Research.[6] The methods and approaches are all capable of:

1. Engaging people, because conversations, involving people, are seen as enablers for dealing with an uncertain future (Van der Heijden 1996, 1997; Aarts en Woerkom 2002); and
2. Allowing skills that are able to create a solution for a complex (or wicked) problem (climate adaptation), to be a crucial part of the process. These skills are in essence to create a solution (e.g. to plan or design) when times are changing and circumstances are uncertain (such as in the case of climate change).

Every part of the research contributes to different phases of theorising and the development of the spatial planning framework. The theory was built up from all these parts, in a constant process of shaping, modifying and redesigning the theory. This research approach does start with its parts, identifies key points and concepts, which in their turn have informed theory forming, hence it reflects the principles of Grounded Theory. As a general definition of Grounded Theory, a methodology developed by Glaser and Strauss (1967) to construct a theory derived from qualitative analysis of data (Corbin and Strauss 2008). In Grounded Theory, the research guides data collection. Core here is theoretical sampling, which is concept driven. Out of the data concepts are developed, which subsequently direct the collection of data. Only relevant concepts are elaborated further and integrated, linking categories around core categories, which are refined and trimmed into a theoretical construct. In essence Grounded Theory can be brought back to three key steps. In the first step key points are identified and around these key points data are collected. In the second step these key points are connected in concepts and the third step integrates the concepts in a theoretical construct. The attractiveness of this research theory is that there is no fixed pattern beforehand, but it focuses on the creation of new insights or innovations and the theory emerges during the process. The nature of the research objective, to develop a planning framework, which is able to include climate adaptation characteristics and facilitates the design of climate adaptive plans, fits very well with such an emerging research process.

[6] In qualitative research there is a widespread spectrum of research types. The general characteristics are that these research approaches focus on words rather then numbers, there is direct contact with 'the field' and data are captured from the inside (e.g. in direct collaboration with participants). Moreover, these research types require emphatic understanding, aim for a holistic overview (which is systemic, encompassing and integrated) and is little standardised in its instrumentation. Words in conversations, stories or ideas, form patterns and these patterns are seen as the result of the research (Miles and Huberman 1994). In this research these patterns often present themselves as designs and plans. Amongst the research types are reflexive approaches, collective action research and collaborative action research in which the researcher is in close contact with the participants in the research environment. In qualitative research it is important to obtain unbiased outcomes, providing the 'right answer' after having included many applications (King et al. 1994). However, in the case of carrying out design related research, it might be required to conduct biased research, as to reach a certain goal of creating a climate adaptive design and/or society.

The research was build up from, initially, designs and concepts such as for instance the *Idea Map Groningen*, the *Floodable Landscape* and the *Zero-Fossil Region*. These designs were to a certain extent developed in planning and policy practice. The second step was the publication of these initial designs as scientific articles in the form of book chapters, conference proceedings or in an academic journal. In the process of publication these initial designs were linked and confronted with existing theories through literature reviews and this formed the basis for extended theoretical research such as for example planning theory or complexity theory. From these theoretical explorations emerging research concepts were developed. Examples of these are Swarm Planning, the Five Layer Approach and B-minus. These concepts formed the input for a new series of designs, in which these concepts were further elaborated. Examples of the latter are the bushfire resilient landscape of Bendigo and the designs for the Peat Colonies. This approach offers more chances for a design-led research, which aims for the development of e new planning framework, then a more traditional approach, which generally starts with an analysis of existing theory followed by the development of research concepts, which subsequently would be applied in experiments or designs, after which the results are published in scientific articles. The way the research was conducted is schematic compared with a more traditional approach in Fig. 1.8.

The research was conducted in four phases (Fig. 1.9). After phase one, the introduction, in the second phase the theoretical framework of Swarm Planning was developed. The theories of complexity, planning and change are used to build up the theory. In the third phase the theory was applied to examples both in the field of adaptation and mitigation to climate change. The final, fourth, phase concludes the results of the research.

1.8 Limitations

The research conducted in the context of this thesis has been a search for connections between many fields of science. The domains of spatial planning and design needed to be connected with climate change, energy and climate adaptation, but also with Complexity Theory, complex systems and self-organisation, and change theory, transition and transformation. This was necessary because the aim of the research, to create a spatial planning framework for a wicked problem as climate adaptation required all the identified fields. However, the cross-disciplinarity of the research has also a backside: inevitable limitations.

Therefore, it has not been the intention of the research to contribute to each of the scientific field mentioned above, but to bring connections and links between the individual fields of research. It has not been the intent to contribute to climate change research, neither it has been the proposition to explore the mathematical and agent-based modelling side of complexity theory. For the purpose of the research it was sufficient to understand the conceptual background of these theories and translate them to the spatial planning and design domain.

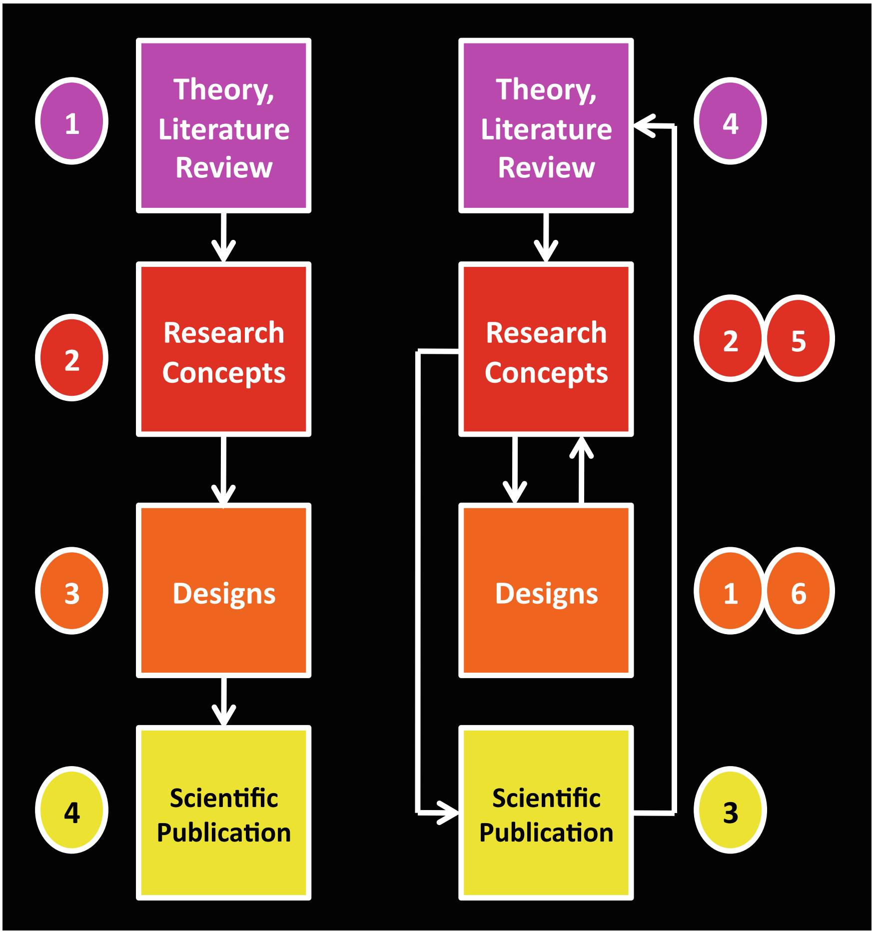

Fig. 1.8 Transition from a traditional to an emergent research process

1.9 Key Concepts and Timeline

Over the course of the research many key points and concepts emerged. Together they led to the building of Swarm Planning theory (Chap. 3). These concepts have not been developed in a well-organised, linear order, but emerged at different moments in the research. Some key concepts were already developed in early stage, while other key points only appeared in the end phase of the research. Figure 1.10 is a reconstruction of the timeline, in which the emergence of the different concepts is shown.

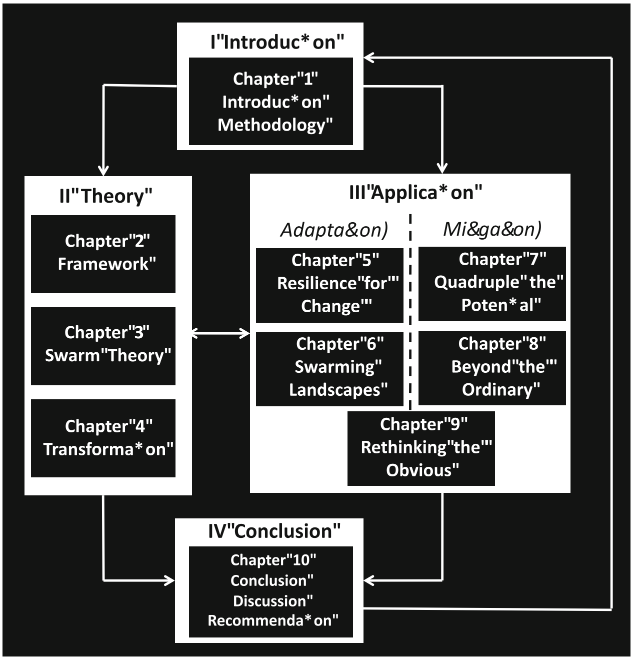

Fig. 1.9 Main phases and structure of the research

In which:

OFF05 = paper Oxford Futures Forum 2005, Oxford (Roggema 2005)

Ravage07 = paper Ravage of the Planet 2007, Bariloche (Roggema and van den Dobbelsteen 2007)

UKSS08 = paper United Kingdom Systems Society 2008, Oxford (Roggema 2008b)

SB08 = paper World Sustainable Building Conference 2008, Melbourne (Roggema and van den Dobbelsteen 2008)

SASBE09 = paper Sustainable and Smart Built Environments 2009, Delft (Roggema and van den Dobbelsteen 2009)

PLEA = paper Passive and Low Energy Architecture 2009, Quebec (Roggema et al. 2009)

Ravage09 = paper Ravage of the Planet 2009, Cape Town (Roggema 2009d)

NCCARF10 = paper National Climate Change Adaptation Research Facility 2010, Gold Coast (Roggema 2010)

NOVA-1 = book chapter Climate Change Adaptation: Ecology, Mitigation and Management. NOVA Publishers (Roggema, Van den Dobbelsteen, Stremke, Mallon 2011)

SEE10 = paper Sustainable Energy and Environment 2010, Hanoi (Roggema 2010)

Tempe11 = two papers Resilience 2011, Tempe (Roggema et al. 2011a, b)

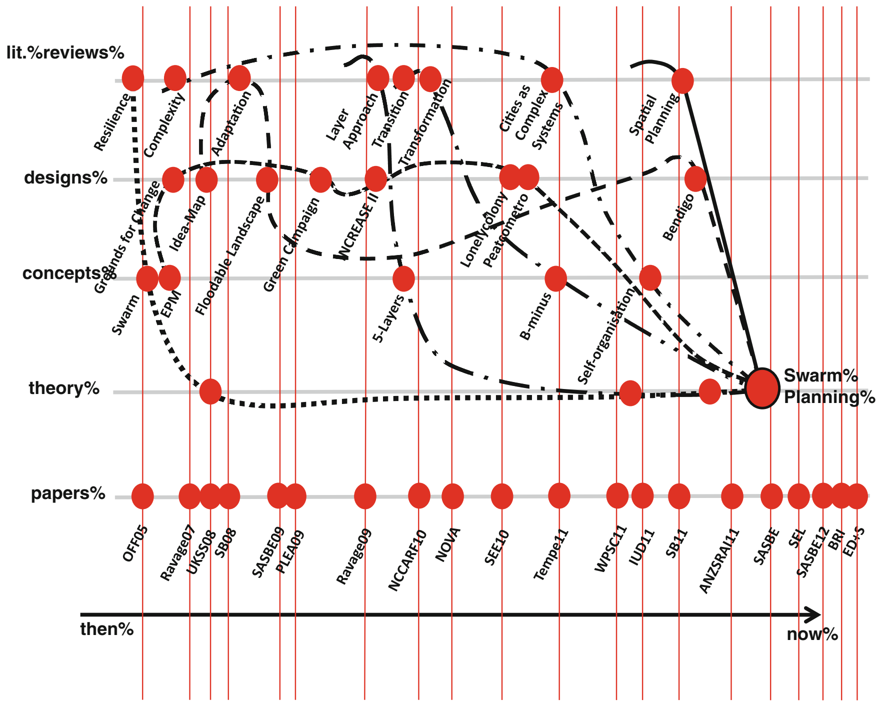

Fig. 1.10 Reconstruction of the timeline of emerging research concepts

WPSC11 = paper World Planning Schools Congress 2011, Perth (Roggema et al. 2011)

IUD = paper 4th International Urban Design Conference 2011, Surfers Paradise (Roggema 2011a)

SB11 = paper World Congress Sustainable Building 2011, Helsinki (Roggema and van den Dobbelsteen 2011)

ANZRSAI11 = paper Australia New Zealand Regional Science Association International Conference, Canberra (Roggema et al. 2011c)

SASBE = journal article Journal of Smart and Sustainable Built Environments (Roggema et al. 2012a)

SEL = book chapter Sustainable Energy Landscapes (Roggema and van den Dobbelsteen 2012)

SASBE12 = paper Sustainable and Smart Built Environments 2012, Sao Paulo (Roggema et al. 2012b)

BRI = journal article Journal for Building Research and Information (Roggema and Van den Dobbelsteen 2012)

ED + S = journal article Sustainability (Roggema et al. 2012b)

In Fig. 1.10 a total of seven research lines are distinguished:

1. The line in which the concept of resilience and the way swarms function is used to contribute to a spatial planning framework which function in a more flexible way than current practice (Chap. 5);
2. The line in which the methodology of Energy Potential Mapping has been developed to inform spatial planning theory and practice how to increase the role of renewable energy sources in regional planning and design. The Grounds for Change design, the design for the Province of Groningen and the Green Campaign design are the main examples (Chap. 7);
3. The line of adaptation emerged from the beginning of the research with the design of the idea map for Groningen (Chap. 5). Thinking in anticipative pathways for climate adaptation was further elaborated in the designs for the floodable landscape (Chap. 6) and Bendigo (Chap. 3);
4. The line of Complexity Theory and its application to cities informed the Swarm Planning Theory and has been used to design the pilot design for Bendigo (Chap. 3);
5. The line of the layer approach contributed to the spatial planning framework as it formed the fundament to create the Five Layer Approach, which forms the basis for the Swarm Planning theory (Chap. 2);
6. The line of transition and transformation informed the theory how fundamental change could be enhanced. The development of the B-minus concept has been derived from this line (Chap. 4);
7. Finally, the Spatial Planning line has been used at the end of the research as the benchmark for the new Spatial Planning framework. It informs the theoretical thinking whether the new framework is authentically new and whether it contributes to emerging thinking within the spatial planning discourse (Chap. 3).

1.10 The Chapters

The Chaps. 2–9 are all published as separate articles in academic journals, as scientific book chapters or in conference proceedings. They all can be read as stand alone articles and are all peer reviewed. The aims, methods and roles for each of the individual chapters are described as follows.

Chapter 1 introduces the research, the methodologies used, the limitations and emerging concepts.

In Chap. 2 the main aim has been to search for approaches that allow for climate adaptive spatial planning. The theories of complex adaptive systems and the layer approach are used to create a spatial planning framework, which can deal with changing circumstances, uncertainty and dynamics. In the planning framework five layers are identified, each with a different time dimension and the properties of complex adaptive systems are used to link spatial elements to specific layers. Subsequently the framework has been used to design a prototype of a climate adaptive region. This chapter is published in the inaugural issue of the *Journal of Sustainable and Smart Built Environments* (SASBE).

The aim of Chap. 3 is to build a planning theory or approach, which is capable of dealing with complex non-linear (wicked) problems, such as climate change. This planning theory is named Swarm Planning. Literature review reveals that the current planning discourse and scientific publications of recent two years primarily focus on well-defined problems and allocate spatial planning the task to achieve a certain end goal. This implies shortcomings in dealing with complex problems, especially in uncertain times. Therefore, in this chapter Complexity Theory is used to increase the potential in planning to deal with complex problems and circumstances. It is concluded that to improve the adaptive capacity in times of external pressure (e.g. climate change) on the (spatial) system (e.g. the landscape) the system needs to be forced to an instable state before it tips towards higher adaptive capacity. In spatial planning terms, this requires an intervention (enforcing the tipping point) and the attribution of elements in the spatial system with complex adaptive properties to self-organise towards this higher adaptive capacity. This theory has been used in a pilot design for the town of Bendigo, Australia. This chapter is published as a Book Chapter in *Sustainable Energy Landscapes* (Stremke and Van den Dobbelsteen 2012).

The chance of the system from a stable state A towards a new stable state of higher adaptive capacity (B) is in literature usually seen as a transition pathway. In Chap. 4, this process is not described as a transition from the original to a slightly better version of the original, but as a transformation of the original into a fundamental different system. To transform in this way, it is required that the new system 'takes over' the old one, or as described in this chapter, a new wave replaces the existing one. This 'new wave' (system B) can be discovered in two ways. The first way is through the identification of early warning signals, announcing system B, and the second way is through creating tipping points for change. The latter option requires thorough analysis where these points can be developed and the places are assumed to be in the most intense and important nodes in (traffic, water, energy and information) networks, which are therefore analysed in a case study area. This chapter is published in *Sustainability*.

In Chap. 5 the possibilities to design a climate adaptive regional plan in turbulent times is discussed. A complex system is able to increase adaptability in turbulent circumstances if the collective capacity to manage resilience is enhanced. Swarm planning, in the form of a strategic intervention and the capability to self-organise is a way of doing this. In this chapter several existing projects, which can be dubbed swarm planning *avant-la-lettre* are used as inspiration for the regional design. This design includes two swarm principles: on the basis of mapping the energy-potentials and climate impact futures an integrated land-use idea map is developed and the so-called Groningen-impulses, a set of strategic interventions has been proposed. Each of these interventions is subsequently designed in greater detail. This design was part of the development of the regional plan. This chapter has been published in the *proceedings of the UK Systems Society conference "Building Resilience: Responses to a Turbulent World"*, and, in modified and more concise form, has been published in the *proceedings of the World Sustainable Building Conference 2008*, where it was awarded with the prize for best theoretical paper (out of 650).

The way urban and landscape design could deal with uncertainty and increase their resilience is the central focus of Chap. 6. Assuming the landscape as a complex adaptive system, the properties of these systems are applied to the spatial system and its individual components. Learning from swarm behaviour and using this knowledge to inform and 'program' the landscape is then seen as the way to increase the resilience of the system. These principles are used to design the pilot case study of the Floodable Landscape. This chapter has been published in the *proceedings of the 4th International Urban Design Conference "Resilience in Urban Design"*.

In Chap. 7 research, which identifies the harvesting of renewable energy potentials at four different levels of scale has been interlinked. The Supra-regional scale, the regional scale, the local scale and the building scale all have huge potentials to harvest renewable energy sources. When interlinked the supply can easily provide more than current energy demands. Moreover, these potentials can function as the drivers for spatial designs as they direct certain land-uses. This chapter has been published in the *proceedings of the PLEA conference "Architecture, Energy and the Occupant's Perspective"*.

In Chap. 8 the principles of Energy Potential Mapping, as researched for Groningen Province are used as the basis for a conceptual design, as has been developed in the Design Charrette 'INCREASE', and the identification of crucial nodes, where innovations and developments of change are likely to start; the swarm interventions or focal points. In this chapter, the underestimated relationship between energy supply/production and the spatial design on a regional level is illuminated. The network analysis for energy and water determine the location of the focal points and the strategic places in the design for the region. This chapter has been published as a Book Chapter in *Climate Change Adaptation: Ecology, Mitigation and Management*. Climate Change and its Causes, Effects and Prediction-series. NOVA publishers.

The premise of Chap. 9 is that solving new, fundamental different problems with the approaches used to solve the problems of the past will not satisfy. Given the theory that climate change appears in the shape of a staircase (and not in a fluent curve), future change will appear as a fundamentally new problem and therefore, our responses to climate change require a fundamental different approach than the ones used in the past. The Swarm Planning approach, as developed in Chaps. 2– 3, is elaborated in this chapter and used as the approach that can provide this approach. The Five Layers, linked with appropriate time dimensions are provided with the suitable properties of complex adaptive systems and is used to design two pilot designs: the Zero-Fossil Region and the Carbon-Capture Landscape, in which both climate adaptation and mitigation are united. This chapter is published as an invited article in the *Journal of Building Research and Innovation* (Roggema and Van den Dobbelsteen 2012) and is based on two conference papers, published in the *proceedings of the World Planning Schools Conference and the World Sustainable Building Conference 2011*.

Chapter 10 functions as the conclusion of the research, containing a critical reflection and final recommendations.

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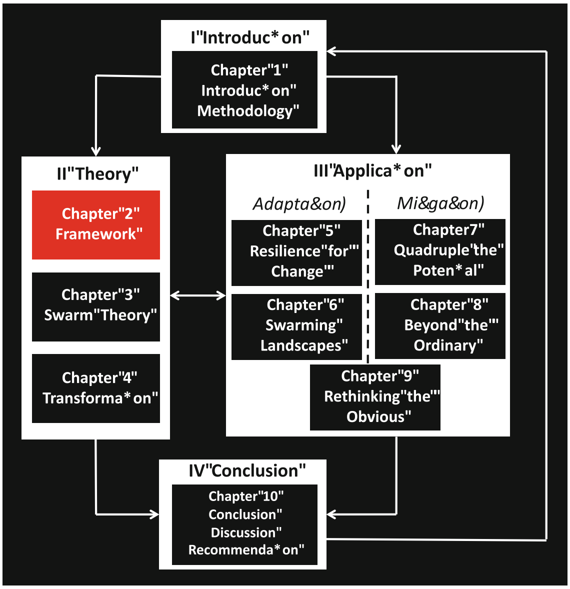
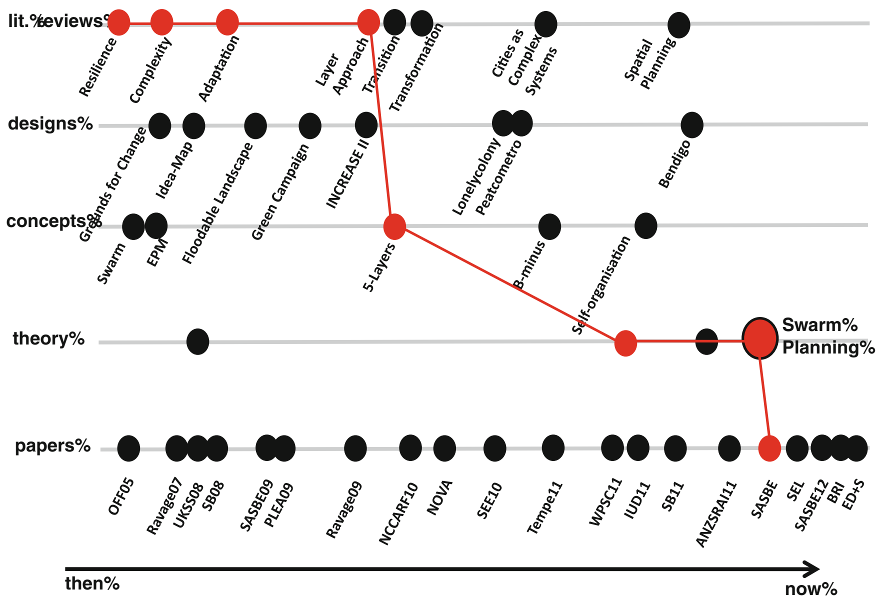
The Bridge: One–Two



After the starting point of the research is defined and the research is framed (in Chap. 1), Chap. 2 is the first chapter presenting results. The first contours of a planning framework become visible. This framework aims to build a bridge between climate adaptation and spatial planning. In order to do so properties of both are unified. Properties of complex adaptive systems, such as adaptive capacity, resilience and vulnerability, amongst others, are defined as spatial elements to make them functional in a spatial planning context. In order to do this, theories of resilience, complexity and adaptation are studied and used to build up the framework. The second element in this chapter is the acknowledgement of the differences in time-dynamic of spatial elements. Some elements change very quickly, while other require longer periods to change. Especially when climate adaptation is concerned, the tension between the long-term of a changing climate and the short-term requirement of adaptation deserve a framework in which the entire spectrum of time dimensions can be represented and used in spatial planning. The newly developed Five Layer Approach, derived and adjusted from the original layer approach, which consists of three layers (underground, networks and occupation), is capable to span the entire width of time dimensions that can be expected from climate change. In each layer spatial elements with identical time-rhythms are accumulated. The Five Layer Approach can be used to design a climate adaptive region and include non-linear and dynamical processes, such as climate adaptation. The approach is tested in the development of Groningen province as a climate adaptive region. The article is published in the Journal of Smart and Sustainable Built Environments (SASBE).



Chapter 2
Towards a Spatial Planning Framework for Climate Adaptation

2.1 Introduction

Scientific literature on climate adaptation has mainly dealt with definition studies. Some of these studies aim to clarify and define terms such as vulnerability, resilience or adaptive capacity (e.g. Folke et al. 2010; Walker et al. 2004; Walker and Salt 2006; Adger et al. 2007). Another group of scholars studied uncertainty and climate change adaptation (e.g. Dessai and Hulme 2004, 2007; Dessai and Van der Sluijs 2007; Kabat 2008; Mearns 2010; Meyer 2011). Others focused on specific hazards and assessed their risks (e.g. Jones 2001; Handmer 2003; Downing et al. 1999; Beer 1997; Weisner et al. 2004). Finally, a share of scientific papers focused on governance and ways to respond to the impacts of climate change (e.g. Adger et al. 2009; Olsson et al. 2006).

Only a limited number of research projects focus on spatial planning for climate adaptation. It is illustrative that '*the Earthscan reader on Adaptation to Climate Change*' (Schipper and Burton 2009) fails to include a chapter on spatial planning. Even '*Planning for Climate Change*' (Davoudi et al. 2009), a major work taking planning as the major theme mainly focuses on processes, policies and specific topics, such as transport. The predominant part of this book focuses on mitigation; only a few pieces cover *spatial* planning, urban form or urban design. With the exception of Wilson (2009), these parts are mainly oriented on cities and urban areas. So far, there is only one book that specifically positions climate adaptation as a challenge for spatial planning (Roggema 2009).

Spatial planning and design is underrepresented in research programmes focusing on climate change, such as the Dutch Climate Changes Spatial Planning programme (www.climatechangesspatialplanning.nl) and the European ESPACE programme (www.espace-project.org). By estimation 10 % of the first programme is specifically oriented on spatial planning, while the output of the second concerns

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R. Roggema, *Swarm Planning*, Springer Theses, DOI: 10.1007/978-94-007-7152-9_2,

an information base, tools and models as well as raising awareness and changing behavioural change, and policy. Therefore we can conclude that these programmes provide knowledge, instruments and data to be used in spatial planning; however, research on spatial planning and design itself is very limited and takes place mainly outside these programmes.

Another problem we distinguish concerns the lack of genuine attempt to cross the borders of scientific areas, applying to various disciplines. For instance, the resilience research community, as represented at the Resilience 2011 conference (www.resilience2011.org), failed to address spatial planning as a major theme, whilst the climate adaptation community, represented at the NCCARF Climate Adaptation Futures conference,[1] did not acknowledge planning as a major tool to facilitate adaptation to climate change. In reverse, the spatial planning community, as convened at the World Planning Schools Congress (www.wpsc2011.com.au), save two design-oriented papers (March and Holland 2011; Roggema et al. 2011), addressed climate adaptation only in regards to specific hazards or coastal issues. A broad and growing body of literature with adaptation to climate change as main topic has been released (see for example: Godschalk and Brower 1989; Godschalk et al. 1999; Berke 1992, 1997; Brower and Schwab 1994, 2002; Beatley 1994, 2009). However, nearly all of these writings address a very specific theme (e.g. coastal management, biodiversity, disasters) or are specifically focused on mitigation (Newman and Boyer 2009) and do not approach climate adaptation as an integrated issue, which would have made them better suitable for usage in spatial planning practices.

A wide range of research and a rich tradition in publications exist on 'Ecological Urbanism' (e.g. Mostafavi 2010), 'Green Urbanism' (e.g. Beatley 2000; Beatley and Newman 2009) or 'Sustainable Cities' (for example: the WIT Press series on The Sustainable City, e.g. Brebbia et al. 2010). The aim for more sustainable, greener cities is often connected to adaptation to climate change. In this paper we limit ourselves to the way systems theory can be of use to climate adaptive cities, regions and landscapes.

2.2 Problem Statement

A reason for the absence of spatial planning in the climate adaptation discourse and vice versa maybe found in the different set of properties. Whereas the connection between energy and spatial planning can be defined as a tension between different disciplines (e.g. technology versus urban design), the tension between adaptation and spatial planning is more fundamental: as explained below, it is a dichotomy between 'tame' and 'wicked'.

The European Conference of Ministers responsible for Regional Planning (CEMAT) (1983) defined spatial planning as the "geographical expression to the

[1] http://www.nccarf.edu.au/conference2010/archives/519

economic, social, cultural and ecological policies of society", "an interdisciplinary and comprehensive approach directed towards a balanced regional development and the physical organization of space according to an overall strategy". They referred to the methods used to influence the distribution of people and activities in spaces of various scales (CEMAT 1983, derived from: en.wikipedia.org/wiki/Spatial_planning).

Brought back to its essence the question answered in spatial planning is: *How much of what needs to be put where?* Therefore, spatial planning focuses mainly on measurable and quantifiable spatial elements. Dalton and Bofna (2003) defined these as: "elements of zero, one, and two dimensions that observers acquire and utilize as anchors for location, and the relationship of these elements to the observer is topological". This makes them very useful in tackling tame problems.

Conklin (2001) characterised tame problems as follows:

- The problem statement is relatively well defined and stable.
- The stopping point is definite: we know when the solution is reached.
- Solution can be objectively evaluated as being right or wrong.
- A problem belongs to a class of problems that can be solved in a similar way.
- Solutions can be tried and abandoned.

Based on their definitions, IPCC and UKCIP consider climate adaptation as "the process or outcome of a process" (Willows and Connell 2003), leading to "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC 2001). Meanwhile, planning is concerned with the spatial organisation of functions across spatial areas and regions. The problem of climate change adaptation is considered 'wicked' (VROM-raad 2007) or even 'superwicked' (Lazarus 2009), whereas spatial planning is used to dealing with 'tame' problems.

According to Rittel and Webber (1973) wicked problems have the following characteristics:

- They have no definite formulation.
- They have no stopping rules.
- Their solutions are not true or false, however better or worse.
- There is no immediate and ultimate test of a solution.
- Every solution is a 'one-shot operation' since there is no opportunity to learn by trial-and-error, every attempt counts significantly.
- They do not have an enumerable (or an exhaustively describable) set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan.
- Every wicked problem is essentially unique.
- Every wicked problem can be considered as a symptom of another (wicked) problem.
- The causes of wicked problems can be explained in numerous ways; the choice of explanation determines the nature of the problem's resolution.
- (With wicked problems) the planner has no right to be wrong.

The mismatch between the natural preference in spatial planning to deal with tame problems and the wicked character of climate change leads to *mal-integration* of climate adaptation in spatial planning and design.

2.3 Objective

Climate change has spatial consequences, as recent weather events such as Katrina or the floods in Queensland, Brazil and Pakistan illustrated. The fact that more than 50 % of the global population lives in cities (United Nations 2008) and over 70 % of these cities are located in vulnerable coastal areas (Kreimer et al. 2003) gives reason to investigate how spatial planning can minimise the effects of these extreme weather events and determine the potential for climate adaptation. Moreover, it provides the opportunity to anticipate future impacts of changes in climate.

In order to prevent the *malintegration* of climate adaptation in spatial planning this paper's objective is to build a bridge between adaptation to climate change and spatial planning and design, hence to lay the foundations for climate-adaptive spatial planning. We propose a planning framework that unifies the properties linked with climate adaptation and spatial planning. The framework will provide a tool to prepare for and anticipate (unforeseen) changes in climate. This framework may be seen as an attempt to anchor a linkage between a 'hard' mathematical and a 'soft' social type of systems (Checkland 1981) in the field of spatial planning. So far, to our knowledge, both of these (as separated subjects nor as linked fields of study) have been only sparsely integrated in spatial planning theory and frameworks.

2.4 Methodology

In order to bring climate adaptation and spatial planning together in a framework the research presented consisted of the following steps (Fig. 2.1):

Literature review

Research was conducted on the theoretical discourses of both climate adaptation and spatial planning suited for climate-adaptive spatial plans. We specifically searched for adaptive and dynamic approaches in spatial planning literature. Complex adaptive systems have the ability to increase their adaptive capacity, which is defined as the capacity of a system to adapt if the environment where the system exists is changing (Carpenter and Brock and Brock 2008), which is what is needed for climate-adaptive spatial planning. We translated the relevant theories and properties of complex adaptive systems into a list of spatial elements.

The framework

For the planning framework we introduced five new layers, each with their own dynamic and time rhythm. The spatial elements derived from the literature study were aggregated to a list of 12 unified elements and linked to the five layers.

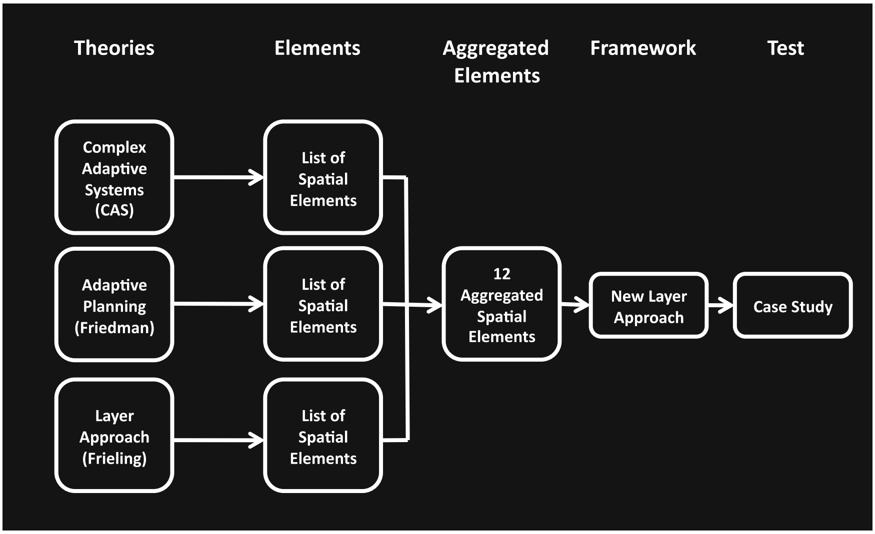


Fig. 2.1 Methodology of the research

Validation

The framework with the five layers and its spatial elements were tested in a case study of the design of a climate-adaptive region.

These three steps will be subsequently discussed (Fig. 2.1).

2.5 Literature Review

In this section, spatial planning literature and complex adaptive systems theory are reviewed. We searched for approaches in spatial planning theory that could deal with adaptive and dynamic processes over a longer time. In reverse, the properties of complex adaptive systems were analysed on their applicability in spatial plans.

2.5.1 Adaptive and Dynamic Approaches in Spatial Planning

Many of the concepts described in spatial planning theory put emphasis on the allocation of functions and only very few include adaptation different 'time rhythms'.

The allocation of functions is the core element in developmental (or 'allocative') planning, both in the positivist and post-positivist planning schools. Positivist planning schools (advocating comprehensive rationality) search for the ultimate truth, are science based and top down (McLoughlin 1969; Allmendinger 2002). Therefore, the positivist planning approach requires much data (Banfield 1973). If problems are complex, as most of the issues are nowadays (De Roo 2006), serious simplification of the problem is necessary (Lindblom 1973). Post-positive planning schools do not use an ultimate truth to allocate functions, but choose a certain perspective to start planning. Collaborative planning or communicative rationality focuses for the allocation of functions on stakeholder involvement and participative processes, while pragmatism and 'New Right' are more market driven (Allmendinger 2002). Developmental or allocative planning is meant to maintain system balances and transform general aims into plans and processes (Friedman 1973). In itself the allocation of functions is an important tool to improve 'system performance', as described by Friedman (see further on). However, in order to deal with the characteristics of climate adaptation the allocation of functions alone is not enough. A planning system that does involve climate adaptation needs to comply with the following conditions:

1. It needs to anticipate, enhance and enforce changes, because climate change is very likely to force changes to the system. Most planning perceptions do not aim to change the system.
2. It needs to be locality specific (Friedman 1973), because climate change differs for specific areas. A locality is a unique configuration of economic activities, divisions of labour, cultural traditions, political alignments, spatial arrangements and physical form (Healey et al. 1988).
3. It needs to bridge (short-term) decisions on projects and long-range comprehensive plans (Robinson 1973). Planning systems focus on the short term. Climate change is a problem that becomes manifest in a mid- to long-term range.

In spatial planning theory, we found two approaches that have the ability to deal with dynamic subjects such as climate adaptation: the layer approach (Frieling et al. 1998) and adaptive planning (Friedman 1973).

The layer approach

The 'layer approach' (Frieling et al. 1998) defines three layers for different timeframes or 'rhythms'. The rhythm of the first layer (water and soil, the underground) is centuries. To a large extent the water system and the soil determine possible uses of land, including the spatial elements that can or cannot function in a certain area. The second layer (networks) has a rhythm of approximately 100 years. Transport and energy networks yet also ecology belongs to this layer, often represented as linear elements. The third layer (occupation) is linked with a timeframe of 20–50 years (one generation). The patterns derived from human use of the landscape are culturally determined: heritage, agriculture, economic functions, recreation and living. Spatial elements, derived from these layers, are represented in Table 2.1.

According to De Hoog et al. (1998) a fourth layer, 'the public domain', can be added to the three of Frieling et al. (1998). This fourth layer is meant to provide impulses at strategic points (nodes, centres) in the urban system (e.g. focal points) and is considered to have a time rhythm of 5–20 years.

The layer theory offers a good basis for adaptation planning, because different time rhythms can be integrated.

Table 2.1 Spatial elements derived from the layer approach

Layer	Spatial elements
1 Underground	Water system, soil
2 Networks	Networks: ecology, water, energy, traffic
3 Occupation	Human uses/different functions: heritage, agriculture, economy, recreation, living

The layer approach is widely practiced in the Netherlands. For instance, this theory was used to develop the regional plan for the province of Groningen. A-biotic, biotic and occupational elements were analysed and used to determine future land use. The analysis of the functional maps of three recent plans (Provincie Groningen 2000, 2006, 2009) shows that approximately 2 % of the area is allowed to change function over a period of 13 years. This means that nearly 98 % of the area cannot undergo any functional change. Explorative research indicates that at least 30 % of the area should be allowed to change to adapt to climate change (Roggema 2007). In this example, the use of the layer approach increased the possibility to change functions over time only marginally. The main reason for this is that, despite the fact that functions with different time horizons were integrated in the plan these functions were still seen as tame elements.

Adaptive planning

The '*planning for change*' model (Fig. 2.2) (Friedman 1973) may also be useful in dealing with climate adaptation. Friedman discerned allocative and adaptive planning.

Adaptive planning aims to adjust existing standards. Climate adaptation can be seen as the trigger for the adjustment of standards. Friedman (1973) described the following key properties:

1. Adaptive planning focuses on specific aims. Securing resources and providing an environment to deal with climate events or hazards are specific climate-related aims.
2. Adaptive planning induces (major) system transformation. Adaptive planning introduces and legitimises new objectives by concentrating only on a few variables that may accomplish this. Spatially, the places where this can be accomplished—the focal points—are starting-points of these changes. A focal point is defined as "a place or thing that is a centre of activity or interest" (Oxford's Dictionary). The type and intensity of networks play an important role to determine the location of focal points. Unplanned space around these focal points gives room for emergent spatial developments, which allows for dynamism[2] (Mitchell Waldrop 1992) to reside. Hence, flexibility is established here.
3. Adaptive planning leads to new actualised standards.

[2] The dynamism of a complex system resides at the margin between order and chaos. Very simple dynamical rules can give rise to extraordinary intricate behaviour (Mitchell Waldrop 1992).

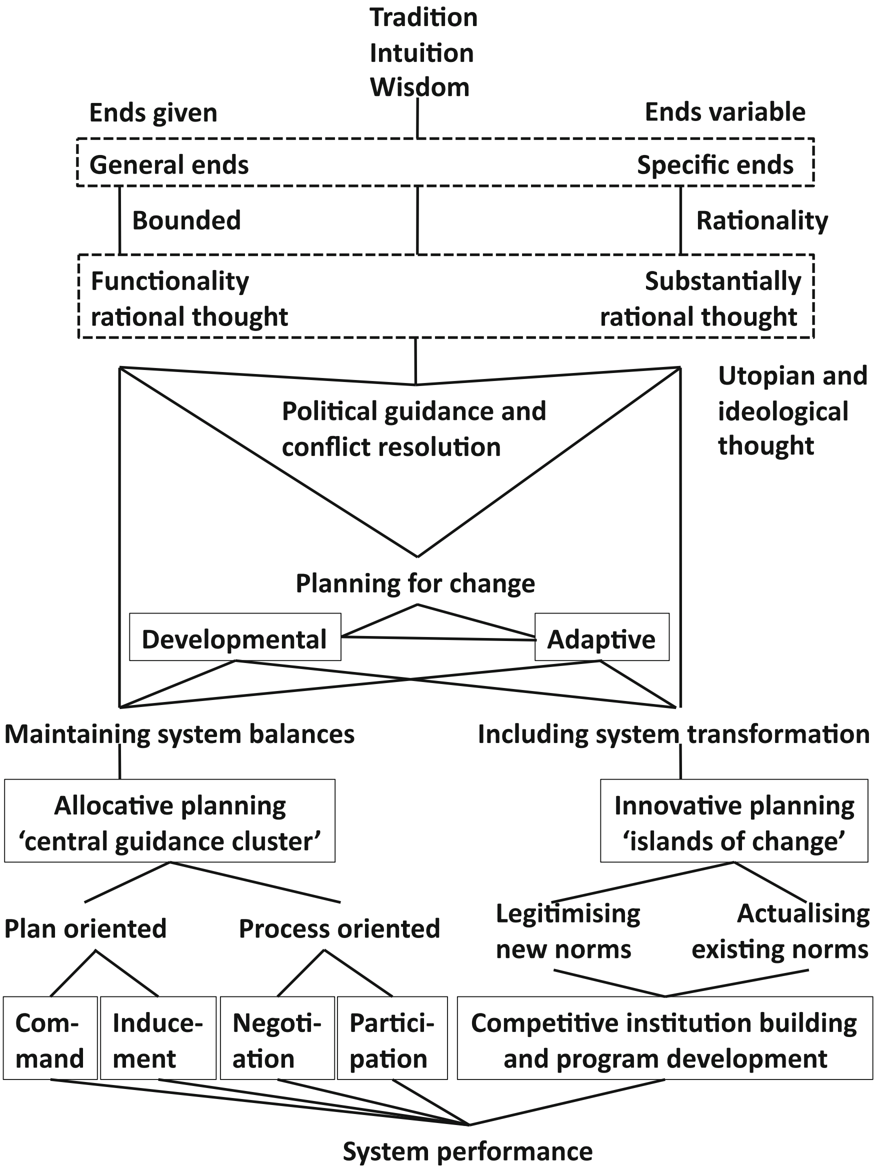


Fig. 2.2 Friedman's conceptual model (Friedman 1973)

4. The process of change, adjustments and adaptability are guided through constant feedback (Casti 1994) regarding the actual consequences of the innovation incited.

In Table 2.2 these properties are translated to spatial elements.

Table 2.2 Spatial elements as derived from adaptive planning

Friedman's description	Spatial elements
Specific aims	(Availability of) natural resources
System transformation	Focal points
	Network types and intensity
	Clear border
	Open influence/Unplanned space
New standards	Functional mix
	Differences in cities and landscapes
	Creative group of people
Feedback	Constant feedback and open changeable area

The layer approach and adaptive planning both deliver spatial elements, which can be used to describe adaptive and dynamic processes. These elements in their turn make it possible to plan for adaptive and dynamic futures. However, in order to complete the set of spatial elements, we must add system properties that enable the adaptive capacity to increase.

2.5.2 The Spatial Properties of Complex Adaptive Systems

Climate adaptation describes a system influenced by and adjusted to the unexpected and/or unknown effects of climate change. Consequently, the aim of climate adaptation is to reduce the impact on and the vulnerability of the system as well as to increase its adaptive capacity (Ministry of Housing, Spatial Planning and the Environment 2008; Swart et al. 2009). Many properties of complex adaptive systems can be related to vulnerability and adaptive capacity. We distinguish the following (Table 2.3): vulnerability, adaptive capacity, resilience, robustness, self-organisation, emergence, self-healing, agility, flexibility, diversity, co-evolution and coexistence.

A system with higher adaptive capacity will be better capable to adapt to the impacts of climate change. We see adaptive capacity therefore as the overarching principle for the properties of Table 2.3. If the adaptive capacity is high, the system will be less vulnerable, more resilient and robust, better at self-organising and self-healing and perform better on all of the listed properties.

The roles of different groups of properties are identified in Fig. 2.3. The overarching aim to improve adaptive capacity is unravelled through the aim to reduce vulnerability and improve robustness and resilience of the system. The second group of properties concerns processes that enable these aims. The third group of properties helps to make these processes function better and become more successful.

In the next section we will translate the properties of Table 2.3 to spatial elements. In the context of this paper no specific attention is paid to the ecological

Table 2.3 Complex adaptive systems properties

Property	Definition	Reference
Adaptive capacity	The ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences	Brooks et al. (2005)
Vulnerability	Physical vulnerability: the capability of structures (the built environment: lifelines, such as water or electricity) to withstand the energy loads associated with extreme events while protecting the occupants, and the location of structures	CDRSS (2006)
	Social vulnerability: the characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard	Weisner et al. (2004)
Resilience	The ability to absorb disturbances, to be changed and then to re-organize and still have the same identity (retain the same basic structure and ways of functioning). It includes the ability to learn from the disturbance	www.resalliance.org
Robustness	The quality of being able to withstand stresses, pressures, or changes in procedure or circumstance. A system, organism or design may be said to be 'robust' if it is capable of coping well with (sometimes unpredictable) variations in its operating environment with minimal damage, alteration or loss of functionality	Massoud Amin (2008)
Self-organisation	The potential to spontaneously and unpredictably develop new forms and structures by itself out of chaos	Merry and Kassavin (1995)
	The ability to spontaneously arrange its components or elements in a purposeful (non-random) manner, under appropriate conditions but without the help of an external agency	Amongst others: Kaufmann (1995); Krugman (1996)

(continued)

Table 2.3 (continued)

Property	Definition	Reference
Emergence	The system moves from a certain state into another. The system becomes, not is. This will happen if certain elements together form new entities. Emergence cannot be planned, only stimulated by creating the starting conditions	Lewes (1875, 412); Berns and Fitzduff (2007); Goldstein (1999); Krugman (1996, 9–29)
Self-healing	A system that uses information, sensing, control and communication technologies to allow it to deal with unforeseen events and minimise their adverse impact through: (1) anticipation of disruptive events (2) look-ahead simulation capability (3) fast isolation and sectionalisation (4) adaptive islanding	Massoud Amin (2008)
Agility	The key characteristics of agile systems are: (1) predicting future opportunities and risks, (2) choosing or designing a technical structure that enables easy integration of new capabilities, which deal with these opportunities and risks, (3) adjusting human organisation to be prepared more readily, (4) including fault tolerant designs and (5) providing information that increases confidence during transition periods	Massoud Amin and Horowitz (2007)
Flexibility	The degree to which the spatial and temporal boundaries are pliable. The extent to which a border may contract or expand, depending on the demands of one domain or the other	Hall and Richter (1988)
Diversity	A greater variety of (city) areas, increasing interactions and thus vitality, attracting talented individuals and strengthening social capital.	Talen (2006); Boyer (1990); Ellin (1996); Lazear (2000)

(continued)

Table 2.3 (continued)

Property	Definition	Reference
Co-evolution	Change of an object triggered by the change of a related object. As a result of co-evolutionary processes collective patterns within groups of communities (or agents) will emerge under certain circumstances	Yip et al. (2008); Sotarauta and Srinivas (2005); Lewin and Volberda (1999); McKelvey and Baum (1999, 8); Volberda and Lewin (2003, 2129)
	Links the emergence of local ideas and collective patterns out of a large number of individual elements. When parts of organisations get in touch with each other, they are able to react to one another (and therefore change), and an accelerating process of growth or reproduction (i.e. local ideas) emerges	Homan (2005)
Coexistence	Property that determines the development of unique characteristics of a group of communities. There is coexistence between different social groups; cultural diversity is apparent; differences in spatial scale are visible; urban innovation is available and economic development probably too	Archined (2009)

aspects of spatial planning and climate adaptation; we mainly focus on the properties of complex adaptive systems as drivers for adaptation in spatial systems. We assume that increasing the number of spatial elements of each propertyleads to lower vulnerability, higher resilience, etcetera.

Vulnerability

A less vulnerable system has the continuous availability of food, water and energy. Designated areas need to be created to produce, supply and store these, and a secure system of distribution (with a backup network) needs to be in place.

A second aspect of vulnerability is the protection of people. If the size and number of flood- or bushfire-prone areas is minimised, people will be better protected and less vulnerable. This can be arranged by introducing protection structures, such as firebreaks or dikes and levees, but also through creating evacuation routes.

Resilience

The essential networks of a resilient system are water, energy, traffic and communication. For immediate action of people during or immediately after a disaster, public spaces need to be specifically designed where people will 'automatically' gather. A good example of resilient structures is buildings that are

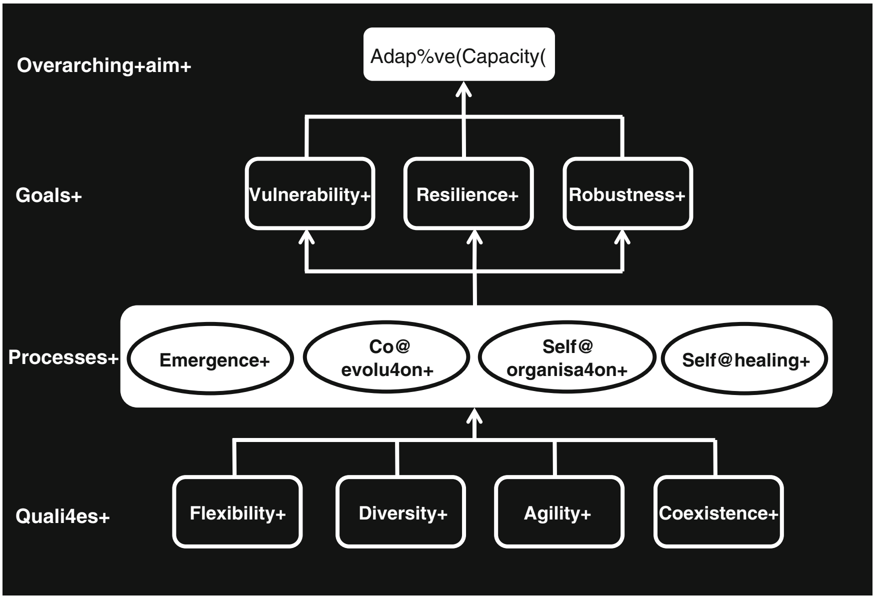


Fig. 2.3 Grouping the properties of a complex adaptive system

suitable to deal with a sudden flood, such as the floatable water-board office building in Amsterdam

Another example is found in designing diverse and intense networks, which contain different options to function (for instance, if one part of the network fails another part will be capable of taking over). Examples are the 'Internet' and the layered stack of harvestable energy potentials in the 'Green Campaign' (De Groene Compagnie, Broersma et al. 2009).

Robustness

If the production systems of food, energy and water remain operating under stress, the robustness of the system will increase. The second form of robustness is to create strong and protective structures against storms, fires or floods. A good example of a robust system is the flexible dike zone as proposed in the ComCoast project (2007), consisting of a fierce dike combined with a multifunctional zone behind and/or in front of this dike.

Self-organisation

The first condition for self-organisation, a clear border, can be determined by the boundaries of a water catchment, the landscape typology or geo-morphological entities. The second condition, small but significant differences in the landscape, is complied with by creating heterogeneity in functions and spatial sizes (large open spaces, meadows, water bodies, averagely and small-sized enclosed spaces). The third condition will be met if energy and information can easily flow through networks, by means of intense networks. A good example of free energy flows is smart grids, which operate as an exchange between energy suppliers and energy demanders. The system, supported by advanced IT, self-organises to find the most optimal use and production. Finally, to generate new relationships between people, accessible public spaces must be realised. Intense nodes, where physical and social networks are linked, are the preferred locations for these.

Emergence

Basic condition for emergence is openness to influence from outside. It allows for spatial interventions that last and continue to develop new patterns. A good example is the 'free-town' of Ruigoord, near Amsterdam, where artists build up their own environment, using materials they found nearby.

Self-healing capacity

Self-healing capacity is imminent when the system contains space for flooding and nature. Parts of the landscape will be easier self-healing if they contain isolated small entities. Adaptive islanding will be possible if autonomous and spatially separable communities can provide for their own food, water and energy. A good example of the latter is Samsø, a small Danish island, which is independent from the mainland in its provision of energy, but which can also produce plenty of food and water (Jørgensen et al. 2007).

Agility

In order to increase agility, networks need to be flexible and provide backup structures. During a transformation humans need to be provided with information and supplies to adjust themselves. The strategy for the Elbe River Basin (Freistaat Sachsen 2006), where several options for adaptation are unified, improves the agility. The different spatial measures start functioning when changes take place.

Flexibility

A flexible system can take different shapes and sizes when the boundary is open for exchange of flows of energy, people and goods. We estimate that if landscape elements of different sizes appear as a 'landscape mosaic' they will attract other functions, people and visitors. Change and adaptation will then happen more easily. Flexible spatial structures are found in response to temporal rising tides or sea levels. For example, the 'green river', a bypass in the river Waal near Nijmegen, fills up in case of supra-normal river discharges (Boer 2010), and the second ground level in Hafencity, Hamburg allows river tides to rise (GHS 2002). Hence, water is stored vertically.

Diversity

Diversity is enhanced when a larger variety of elements in landscape or city increase interactions, allowing for greater vitality, attracting talented individuals and social capital (Florida 2005). Diversity increases when cities and landscapes contain a spatial and functional mix of elements. A good example is the NDSM area in the Northern part of Amsterdam, where small enterprises, creative artists, new media and events transformed an old shipyard.

Co-evolution

Co-evolution occurs when elements in the landscape—such as roads, villages, waterways, energy plants, forests or farms, yet also sediments, soil, trees and others—are triggered by each other or a spatial intervention. Landscape-shaping processes will co-evolve and collective patterns are the result. Locations where major effects can be expected are determined by the intensity of local networks.

A good example is 'Building with Nature' (Waterman 2008). A specific intervention in the natural system, for instance in the form of sand suppletion, will catalyse natural processes of landscape forming such as the extension of sand dunes, beaches and natural reserves. These principles are used in the Zandmotor ('sand engine') to generate a more robust coastal defence in front of the Western Dutch coast.

Coexistence

When social, spatial and cultural differences are apparent in urban areas and rural communities, communities with their own characteristics coexist and innovation is likely to occur. Specific identities in living areas will emerge if overlapping spatial structures and combinations of functions are present. A good example of this happened in New Orleans, after Katrina. In coexistence with the governmental rebuilding efforts, the MIR initiative (www.makeitrightnola.com) provided immediate housing in a striking manner.

Next step

We illuminated spatial elements belonging to the layer approach, adaptive planning or as property of complex adaptive systems. Within and between these sets there is overlap of similar spatial elements, which will be discussed below.

2.6 The Framework

The development of a framework, in which spatial planning and climate change adaptation can be unified, consists of three steps: aggregation of the spatial elements, definition of time rhythms, and linkage of aggregated spatial elements with specific layers.

2.6.1 Aggregated Spatial Elements

The first step is to aggregate spatial elements as derived from the layer approach, adaptive planning and the properties of complex adaptive systems into 12 coherent spatial groups. Specific spatial entities, such as networks, spatial reserves, public spaces, landmarks or nodes, are part of the properties of complex adaptive systems. Subsequently, similar spatial entities are combined and aggregated to 12 spatial groups.

For example, the spatial element of 'networks', derived from resilience, self-organisation, co-evolution (all complex adaptive systems properties), system transformation (an adaptive planning property) and the network layer are combined with intense nodes (local ideas), new patterns (emergence) and flexible structures (agility) into one coherent spatial group called 'intensity of networks'.

This aggregation led to 12 distinguished groups. Every group has a specific 'rhythm', i.e. the period of time over which it tends to change. Some of the coherent spatial groups are long-lasting and hardly change (for instance: networks, resources), while others change frequently and over short time periods (for instance: unplanned space).

2.6.2 Definition of Time Rhythms: Layers

The layer approach, which defines different time rhythms, was used to allocate the different groups of spatial elements, each with their specific dynamics (e.g. the timeframe over with they tend to change), to a suitable layer. The three layers of Frieling et al. (1998) with the addition of De Hoog et al.s' fourth layer (1998) were used as the basis. We have chosen to take time rhythms as a basis for the framework, because this enables connecting different time-horizons, which is extremely helpful in integrating long-term changes, such as climate change. In order to include the highly dynamic, emergent properties of systems, we propose a new, fifth layer ('unplanned space'), which has the shortest time rhythm (1–5 years). The time factor, the direction and strength of changed spatial behaviour can be shown in this layer. The layer is process oriented, as it illustrates starting-points of developments (emergent places) and the surrounding unplanned space.

Table 2.4 compares the existing layer approach with the five layers we propose.

The five layers (Fig. 2.4) are part of the planning framework for climate adaptation and are capable to cover time dynamics of every spatial group.

The dynamics, the time rhythm and the changeability of the layers were defined as follows (Roggema et al. 2011):

1. *Networks* are adjustable, but remain steady over longer periods. To build a new network (a road, electricity grid) takes up to 10 years. Once these networks have been built, they hardly change 100 years after. The ecological network is specific, as it can be manmade but generally emerges naturally. These networks remain for a long period.

Table 2.4 Comparison of layer approaches: *left*, the layers of Frieling et al. (1998) and De Hoog et al. (1998) and *right*, the authors' proposal

Existing layer approach	Proposed layers
1. Underground (centuries)	4. Natural resources (20–100 years)
2. Networks (100 year)	1. Networks (10–100 years)
3. Occupation (20–50 years)	5. Emergent occupation patterns (3–10 years)
4. Public domain (5–20 years)	2. Focal points (5–10 years)
–	3. Unplanned space (1–10 years)

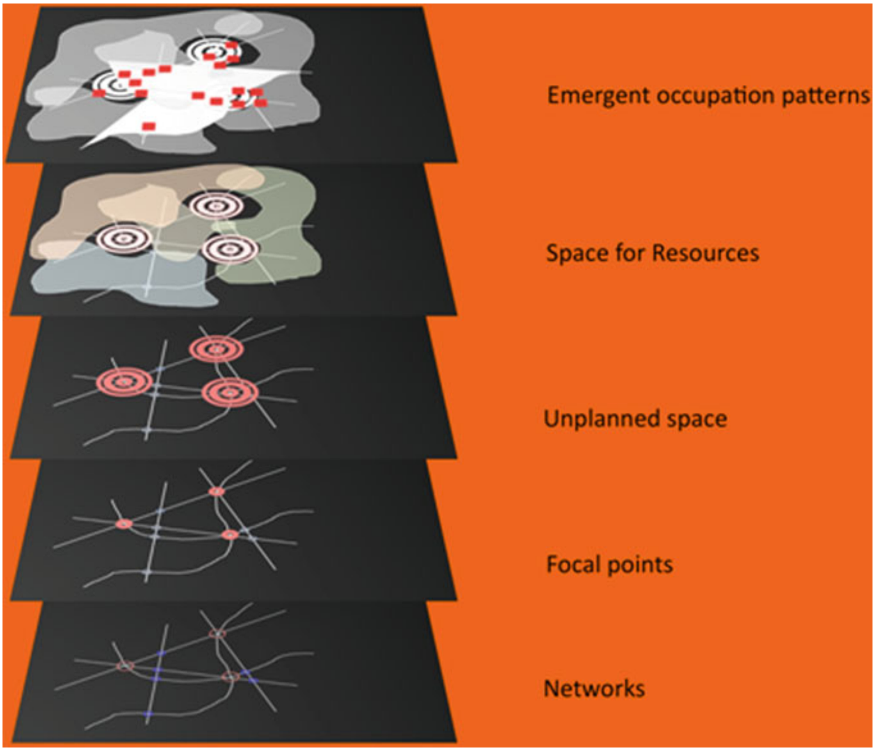


Fig. 2.4 Adjusted layer theory for climate adaptation planning

2. Network linkages determine the *focal points* and they can change, but also stay the same over longer periods. Changes in network patterns, which may occur every 5–20 years, direct them.
3. *Unplanned space* is highly dynamic, because change needs to be possible during a hazard when the space is temporarily used differently. After the hazard, the space becomes unplanned again. The area changes back and forth during 1–10 years.
4. The underground determines locations for *natural resources*, such as food, water, energy and nature and preserves them on the longer term. These locations are long lasting, steady and will change only after rigorous changes in circumstances, e.g. long droughts, cold periods or heat. These types of changes only occur over centuries, if at all.
5. In the fifth layer *occupation patterns emerge* over time and adjust to changing circumstances. This layer is characterised as ‘slow pace dynamic’. It will change if new demands self-organise into new patterns, but these patterns are usually upcoming or declining over periods of 3-10 years.

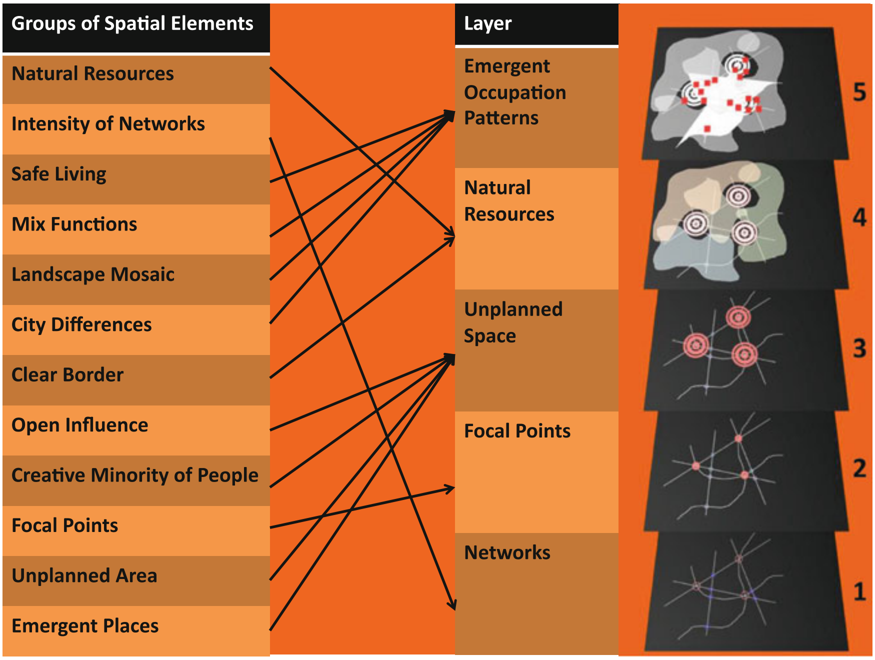


Fig. 2.5 The coherent spatial groups linked with layers

2.6.3 Linking Spatial Elements with Layers

After aggregating the spatial elements in groups and defining the dynamics of each of the layers, every spatial group is linked with one of the five layers (Fig. 2.5).

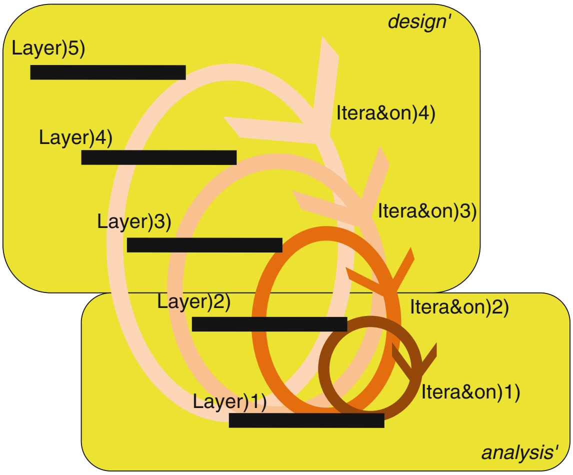
Concluding, the planning framework we propose consists of the following five layers:

- Layer 1: The *networks* layer links with 'intensity of networks'. The road, water, ecology and energy networks are part of this layer. If networks are flexible structures and designed to be fault tolerant, the agility, self-organisation and resilience of the system will improve.
- Layer 2: The *focal points* layer links with 'focal oints'. The most significant nodes, i.e. where different and intense networks cross one another, belong to this layer. These nodes are the public spaces and landmarks in the system, where interactions take place and developments can emerge. Processes, such as co-evolution and self-organisation, are likely to originate here. Adding, by means of planning, additional network layers and linking them to these points will increase the likelihood of emergence and subsequently will cause system transformation and increase the resilience of the system. However, the 'planning' choice of where the intensification is allowed or stimulated, needs to be determined by 'good' social and environmental emergence, for instance where

the contribution to the safety of environments (e.g. the most flood or fire prone areas) or the relief of poverty is largest. These points can be seen as bifurcation points, the points and moments where a system transforms to another stable state (amongst others: Portugali 2000). Here, spatial interventions and impulses start processes and developments that are capable of anticipating future changes and that increase the adaptive capacity of a system. By actively directing the nodes in the networks, processes of action and reaction will start and individual actors in the system will 'automatically' start to adjust in the most optimal way.

- Layer 3: The *unplanned space* layer links with 'open influence', 'small group of people', 'unplanned area' and 'emergent places'. The area surrounding the focal points remains free of any specific function but can be occupied when a sudden event happens. For instance, when heavy rainfall causes flooding, these unplanned spaces are the areas for inundation and temporary occupation. When the system is open for influences from outside, interventions caused by natural factors may take place, requiring the unplanned space to emerge further. Unplanned space gives room to processes of self-organisation, in which feedbacks lead to new standards of a more flexible system. Despite the fact that it is common sense to approach spatial planning in this way (e.g. keeping spatial options open for unexpected future change), the impacts of climate change are often sudden, disasters become more severe and this requires larger spaces than are provided in regular planning processes (if this is being done in current practice at all). The creation of unplanned space also implies a certain opinion in the debate regarding densification of urban areas in order to be more sustainable (e.g. public transport, energy use). In our opinion, sustainability will largely depend on the scale the spatial entities are configured. Taking climate adaptation space as the perspective, an ideal balance between unplanned space and urban entities would consist of compact urban precincts with open spaces in between or, outside the city, compact villages or small towns surrounded by free space. As a result of this, the densities at the metropolitan level may be lower, but the densities within the urban entities are high, in order to create free space around it. The unplanned space will, after having been 'used' to cater for sudden climate events, return to its unplanned status and will remain unplanned until the moment it is needed again.
- Layer 4: The *natural resources* layer links with 'clear border' and 'natural resources'. Based on existing soil and water conditions, areas for the production of food, drinking water and energy as well as the location of nature reserves can be determined. To create a robust and less vulnerable system, these spatial reserves must be safeguarded.
- Layer 5: The *emergent occupation patterns* layer links with 'safe living', 'mix of functions', 'landscape-mosaic' and 'city differences'. The space required to deal with climate hazards (floods, fires, heat and droughts) provides safe living environments, different mixes of functions in the landscape and in the city. They offer specific identities, landmarks and entities. Furthermore, they increase the diversity, flexibility, self-healing capacity and robustness, whilst they decrease the vulnerability of the system.

Fig. 2.6 The framework in practice



When the framework is used in practice, the five layers will not be designed simultaneously. The proposed way to use the framework is in a sequential process of several iterations (Fig. 2.6), of which the first one is mainly analytical and aiming to identify the focal points. The other stages in the process then design unplanned space (iteration two), and subsequently spaces for resources and occupation. As shown in Fig. 2.6, this must be seen as a cyclical process: in the first iteration layer one and two are connected, while in the second iteration layer three is connected to both layers one and two. The process repeats itself in iteration three, where layer four is connected to layers one, two and three, and so forth. This cyclical, iterative process facilitates setting priorities, especially by choosing the most important focal points first and then designing the required unplanned space around it. The rest will follow as a result of these first choices. Now that this framework has been defined, it can be used to develop climate-adaptive spatial plans.

2.7 Validation

The spatial planning framework was used to develop a regional adaptive plan for the Dutch province of Groningen. For a proper validation the adaptive plan was compared with the current prevailing regional plan. This plan is, according to Dutch standards, innovative in the way that it integrates several sectors that are normally separated in thematic plans. Apart from this, the prevailing plan represents a business as usual approach, in which the area is planned for, creating the conditions for an economically most viable future. This means that aspects such as focal points and unplanned space are not seen as essential and not represented in the plan. The security of resources, provision of water, energy and food is seen as a non-regional problem and can and will be solved through import and export of goods. Safety, such as the protection against flooding, is arranged through the implementation of techno-engineering solutions (e.g. strengthening and heightening of the dike), instead of through creating resilient structures, capable of withstanding unprecedented future change (e.g. building with nature, multi-layered dike-zone). The plan can therefore be seen as a continuation of recent policy-decisions rather than a dynamic way of planning, which might bypass current planning constraints.

2.7.1 Prevailing Regional Plan

The prevailing regional plan for the province of Groningen was set (2009). Regional policies for spatial affairs, traffic, water and the environment were integrated into this plan (Provincie Groningen 2009). The policies were brought together on one regional map. The five layers were used to analyse the adaptive capacity of the prevailing plan.

1. Water, ecological, transport and energy networks exist, but are neither related to one another nor seen as the drivers for development.
2. Where networks intersect, nodes appear where change originates, but in the regional plan these focal points are not defined as such.
3. Every hectare has been planned for; there is no unplanned space.
4. Large parts are agricultural and the natural resource ‘food’ is strongly represented in the plan. However, this resource is mainly meant for export. The water supply and natural reserves are arranged for at a level that just satisfies current demand. If a sudden change happens and more water resources are needed, the space cannot be provided. No areas are reserved for energy supply other than the major power plants in the Eems harbour, which mostly provide the rest of the country with electricity. Spatial reservations for ‘natural resources’ are limited.
5. Occupation patterns emerge in the city of Groningen, where new and creative processes are stimulated. Outside this main city, historic landmarks and heritage landscapes are protected. Occupation patterns may emerge, but they are coincidental and not the result of deliberate planning. Safe living is provided through a coastal defence in the form of a single dike, which complies with current safety standards. Despite the fact that Dutch protection standards are very high, an accelerated sea level rise, high tide and storm surge may cause flooding, putting the economic assets (e.g. living and gas extraction) under risk.

The prevailing regional plan can thus be characterised as a continuation of an ongoing spatial organisation. The plan neither focuses on developing processes nor on the emergence of new structures and patterns. The plan only proposes a few adjustments, such as the corridor alongside the motorway to the east, new living areas to the east and west of Groningen city and small adjustments to the ecological main structure. In conclusion, the adaptive capacity, based on the layer-by-layer analysis, is not very high.

2.7.2 A Climate-Adaptive Regional Plan

The spatial planning framework discussed in Sect. 2.6 was used as a step-by-step approach to construct an alternative regional plan, aiming to improve the adaptive capacity of the area.

In the first layer the major networks were determined (Fig. 2.7). Bundles of networks, where roads, railways, energy networks, ecological corridors and

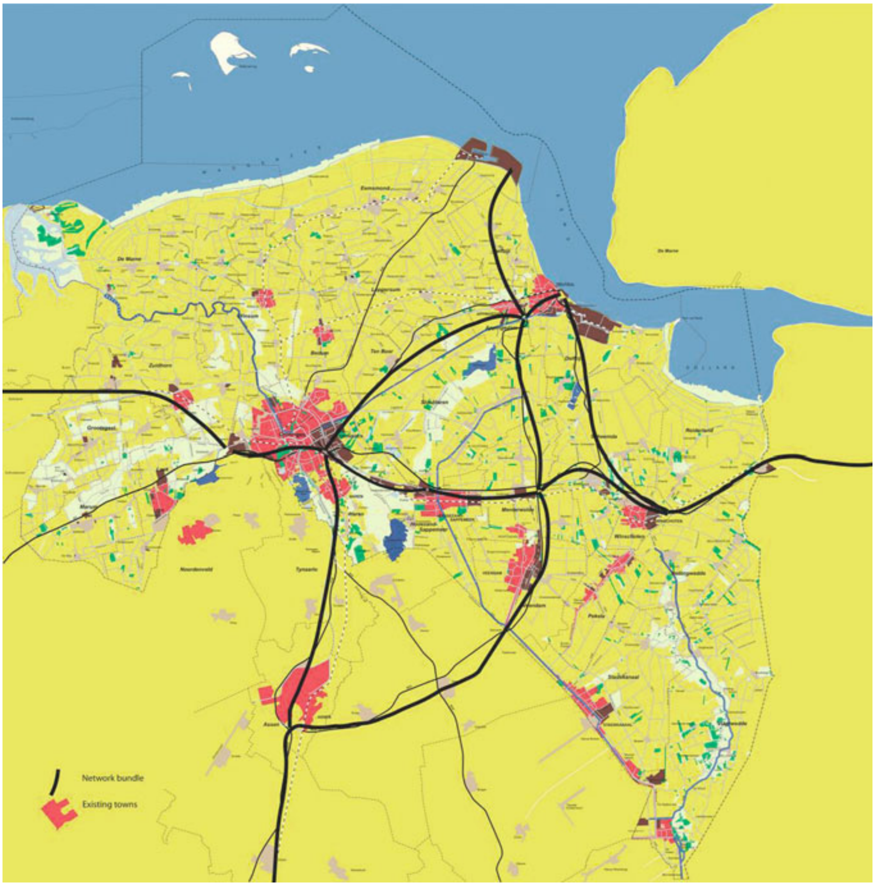


Fig. 2.7 Layer 1, main bundles of networks in the province of Groningen

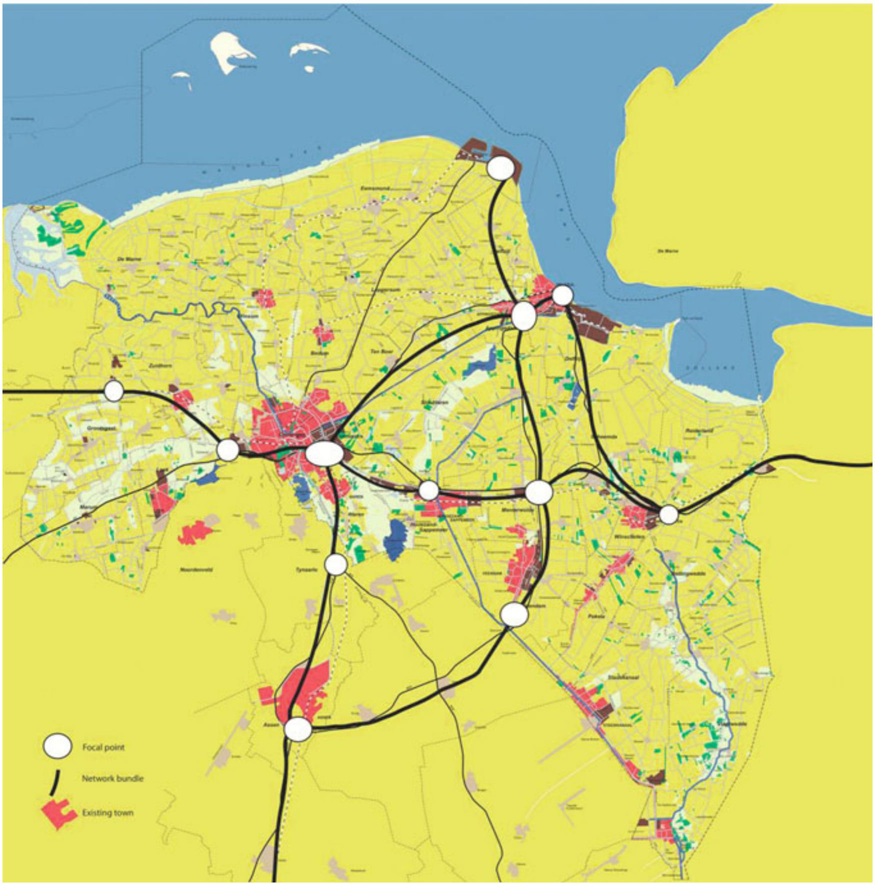


Fig. 2.8 Layer 2, focal points in the province of Groningen

waterways are combined, function as the main drivers of activities. Many of these networks are flexible and contain back-up structures, allowing the system to keep operating when parts of the network fail.

The first iteration illuminates the identification and planning of the crucial focal points. In the focal points where bundles of networks intersect (Fig. 2.8) interactions are likely to be more intense and auto-develop emergent processes. In these nodes people come together and exchange ideas. And here they anticipate and respond to future changes. When a system transformation is required to increase resilience, this is likely to start and happen here. Likewise, interventions consciously planned to enhance system change are likely to be most successful in these locations. The identification of these 'places of intervention' requires further elaboration, since they play a strategic role in the entire framework.

The focal points determine the places where emergent processes may start. However, these self-organising processes require unplanned space (Fig. 2.9)

Fig. 2.9 Layer 3, unplanned space in the province of Groningen

around them, allowing for free developments and occurrence of feedback mechanisms. These spaces are identified and designed in iteration two. For instance, in case of flooding, these areas around focal points can transform into water storage basins. In case of a heat wave, these areas can be used to provide cooling shelters.

Around a focal point the first zone of influence, i.e. where transformations take place most immediately is identified. Beyond this zone unplanned space is reserved to accommodate uncertain developments. If the distance between two focal points is long enough and there is space on or along the network bundle, new emergent places may develop. These emergent focal points will subsequently develop a zone of influence and unplanned space around them. Through short-term adaptation these zones connected to network bundles will be highly dynamic and capable of changing and dealing with unexpected changes.

In the areas outside the highly dynamic zones, the topography, soil and water system determine the most optimal locations for food and energy supply, water

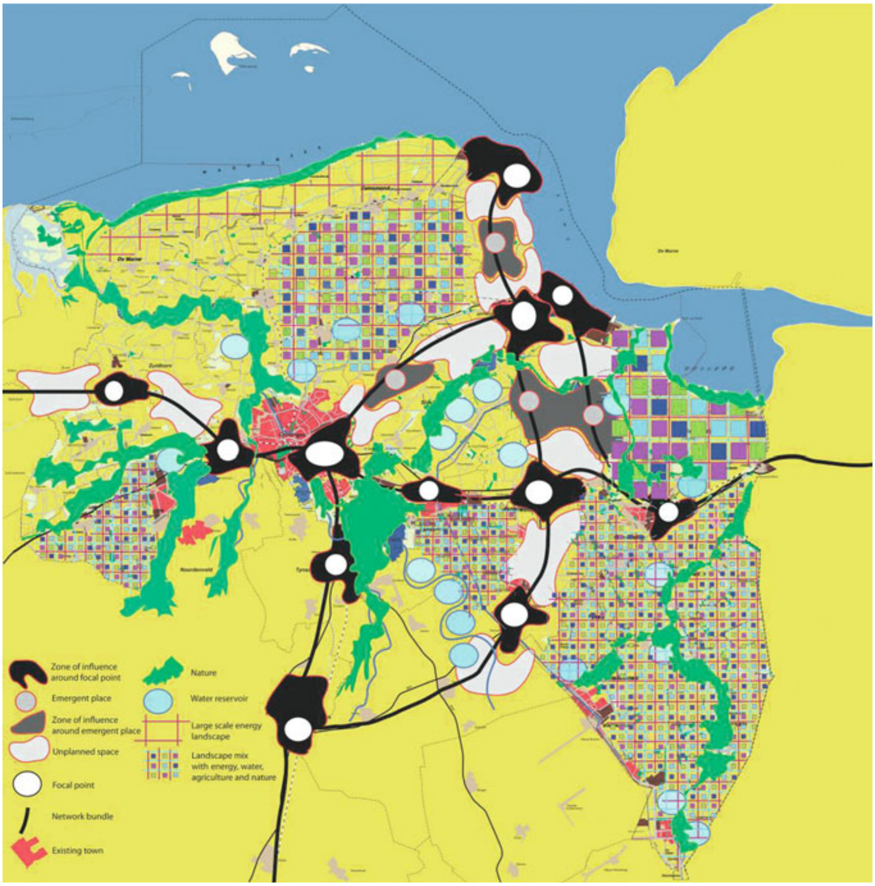


Fig. 2.10 Layer 4, space for natural resources in the province of Groningen

storage and ecological structures (Fig. 2.10) in the third iteration of the design process. The patterns occurring in these spatial reserves for natural resources are related to the spatial densities in the landscape: wide and open versus small and condensed. Much space is allocated for the storage of water, because both agriculture and humans require a lot and in the future water will become scarce in summer. As a result of the allocation of spatial reserves the area will be less vulnerable and more robust to external shocks and unprecedented impacts of climate change. In rural areas the function mix ensures a great diversity and flexibility, allowing for easy adjustment and self-healing capacity in case the environment changes.

The final step in constructing a climate-adaptive regional plan, iteration four, incorporates the increase of functional differences in urban areas and the arrangement of safe areas to live (Fig. 2.11). In the Groningen case study 'safe living' mainly implies a thorough coastal defence. In the plan this was taken care of by introducing a defence zone, consisting of multiple dikes and an intermediate flood

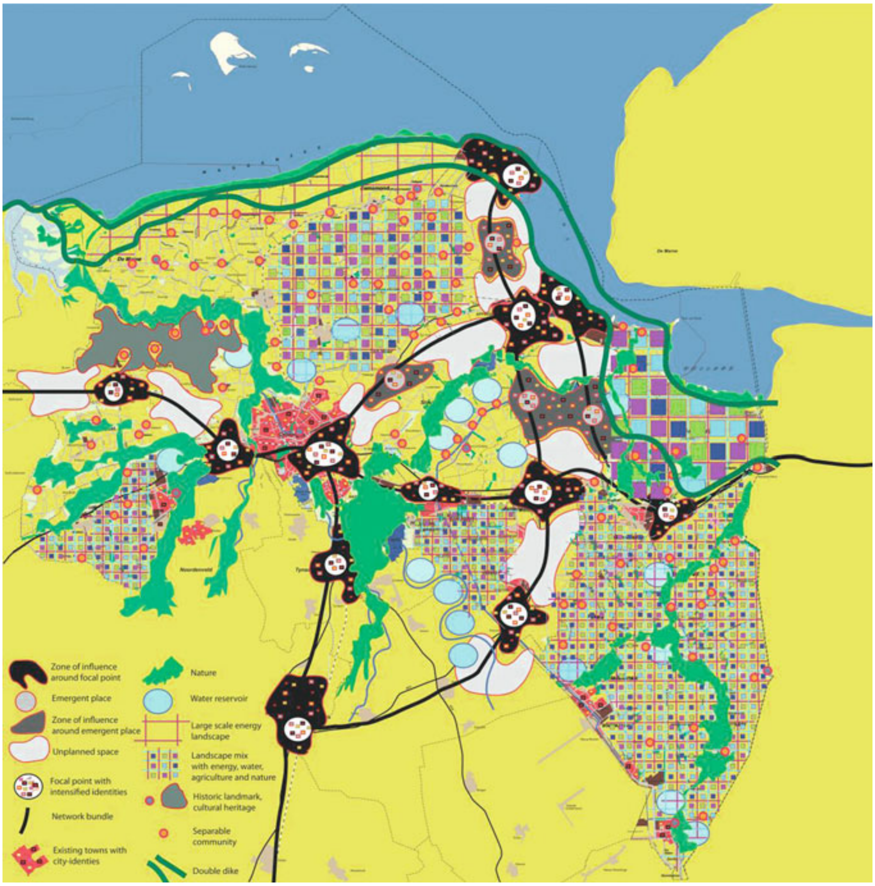


Fig. 2.11 Layer 5, emergent occupation patterns in the province of Groningen

Table 2.5 Comparison of the prevailing regional plan and the alternative adaptive plan

	Prevailing plan	Adaptive plan
Layer 1, networks	Existing, but not connected	Resilience, flexibility, agility
Layer 2, focal points	Absent	Resilience, co-evolution, system transformation
Layer 3, unplanned space	No unplanned space	Feedback, open influence, self-organisation, emergence
Layer 4, natural resources	Food production, water and ecology to current standards	Vulnerability, robustness, diversity, flexibility, self-healing
Layer 5, emergent occupation	Current safety standards, coincidental occupation patterns	Robustness, vulnerability, self-healing, diversity, flexibility, coexistence, new standards

mitigation zone. Inland from this zone safety levels are much higher than current standards. Hence, the region becomes a more robust and less vulnerable system, which will also have self-healing capacity if one of the dikes breeches.

The other aspect of the fifth layer—emergent occupation patterns—will increase the diversity and flexibility of the system, allowing for coexistence and new standards to emerge. A mix of functions in intense urban areas will stimulate interaction within and between communities. This mix of people, social groups and urban functions increases the capability to adapt quickly and easily, enhancing the adaptive capacity.

2.7.3 Conclusions

Every layer of the proposed planning framework contributes to an improved adaptive capacity of the entire system. The system will therefore be capable to deal with unexpected and unforeseeable changes and able to anticipate these. When the climate-adaptive regional plan is compared with the prevailing regional plan (Table 2.5), the prevailing plan has a strong focus on existing standards and allocation of functions, whereas the alternative plan is oriented on occurring processes, allowing the processes to emerge and develop over time. This process orientation enables to include the properties of complex adaptive systems, and by doing so improving the adaptive capacity, i.e. enabling better adaptation to the impacts of climate change.

The benefits of the alternative adaptive plan are threefold:

1. It enables spatial systems to adapt to climate change;
2. It includes a range of time dimensions using of five layers;
3. It enriches the pallet of spatial interventions and elements to design a climate adaptive spatial plan.

2.8 Discussion

Several remarks can be made on the research presented:

1. The case study illustrates that if the properties of complex adaptive systems are defined as spatial elements, an alternative regional design can be made. Each of the properties has an extensive theoretical background, which within the time limits of our research could not be studied in its full scope. Therefore, further elaboration of each of these properties and their definition as spatial elements is recommended.
2. The layer approach offers a wide range of rhythms, which covers spatial processes that develop over different timeframes. The consecutive layers offer the opportunity to link all spatial elements to a specific layer. However, appointing

a layer for every spatial element also implies the negligence of connections between the layers. It is therefore recommended that this aspect of the planning framework will be further elaborated.

3. The case study results show that an adaptive plan can be created using the planning framework as constructed in this paper. Nevertheless, the case study has not been tested in a real life planning process, where politically contested decision-making occurs. Therefore, the case study provides insights in the theoretical potential of the framework but requires further testing in a real life policy context.
4. The step-by-step approach using the layers is basically a rational 'from start to finish' process, which overlooks the dimension of design. Integration of different elements belonging to different layers, iterative design, and analysis of the results can be an improvement to the proposed planning framework.

2.9 Conclusions

Frameworks used in current spatial planning practices predominantly focus on quantifying the current needs and those of the near future. In many occasions the allocation of functions leads to 'blueprint' plans. Therefore, current spatial plans mainly focus on fixing the future in certain standards and quantities of allocated functions in space. These plans have difficulties to adapt to changes, as they are stacked with fixed (and unchangeable) standards. This characteristic of spatial planning causes a problematic integration and representation of climate change issues in spatial plans.

Therefore, we argue that putting emphasis on properties of complex adaptive systems and making them part of a spatial planning framework improves climate adaptation in spatial planning. Review of these properties illustrates that it is possible to define them in a spatial manner and to link them to a certain time rhythm and corresponding layer. The five layers we distinguish offer the full range of time dimensions, within which the spatial elements can find their spot. Due to the fact that all spatial elements are derived from complex adaptive systems properties, their use in a spatial planning process improves adaptation potential of the plan.

The case study—creating an adaptive plan for the Dutch province of Groningen—demonstrates that the framework delivers a spatial layout with the flexibility to adapt. This is an important feat of the framework, since it offers the potential to adjust an area when required by changing circumstances. It indicates that different time-horizons can become part of spatial planning. The spatial layout of the region is flexible enough to adjust space and usage, and to change the area every moment in time.

Our research embodies the first attempt to develop a climate-adaptive spatial planning framework, which specifically includes non-linear and dynamic processes. The research presented in this paper forms the start of filling the gap between climate adaptation and spatial planning. It needs to be seen as a first step towards a more sophisticated framework that requires further elaboration.

Despite the fact that this framework offers promising results, some weaknesses can be distinguished as well. Firstly, the framework has not been extensively tested yet in practice. New experiments using this new framework are strongly encouraged, because they can lead to deeper insights into the applicability of the framework in practice. Secondly, network research related to the emergence and the flexibility aspects of the framework could be extended.

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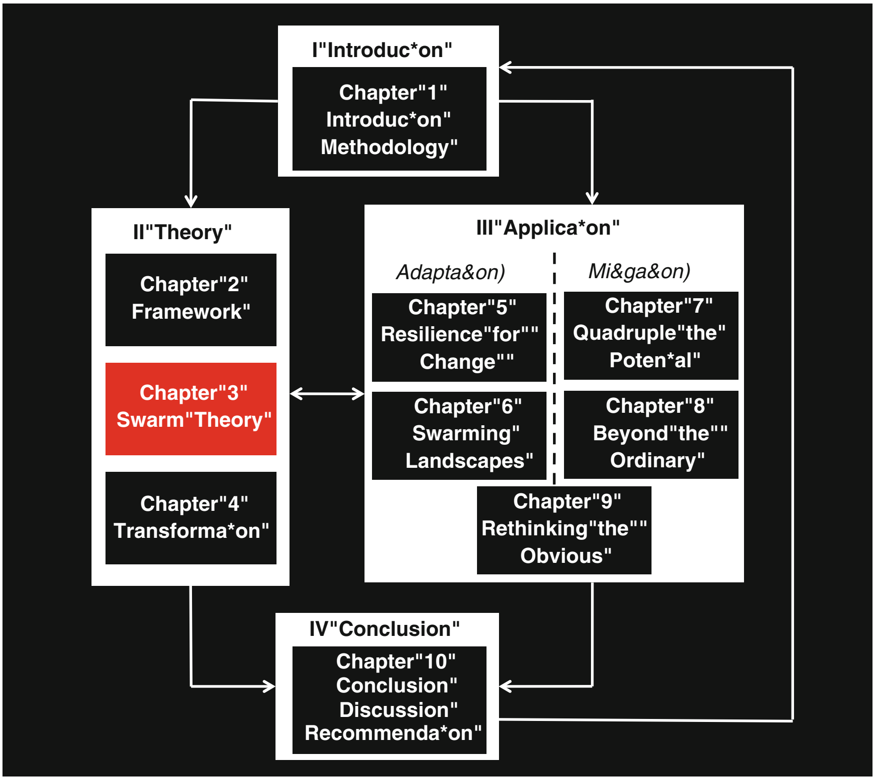
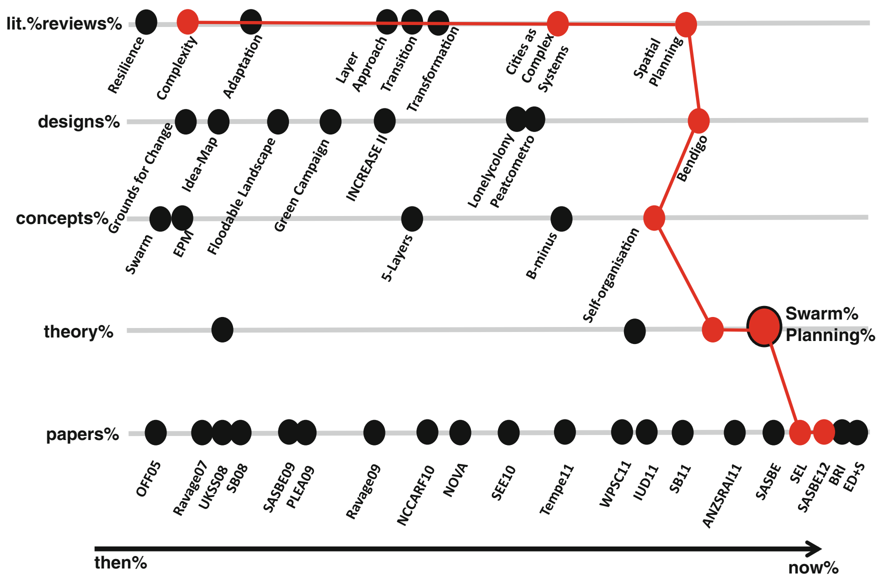
The Bridge: Two–Three



The framework of Chap. 2 is taken as the basis for further development in Chap. 3. In this chapter Swarm Planning theory is build up. Complexity theory and Spatial Planning Theory are used to create the fundamentals of the theory. The rationale for needing this new theory lies in the fact that current spatial planning paradigms both seen from an academic as practice perspective, lack the possibility to deal with problems that are *not* straightforward, clearly defined and predictable: the so-called wicked problems. The majority of planning literature is still focusing on well-known problems and is mainly operational within a governmental context. An analysis of the recent two years of academic publications shows that 94 % of the articles discuss traditional topics and approaches.

A way to overcome this is to incorporate the findings of complexity theory in spatial planning theory. This article/chapter introduces the principles of 'Swarm Planning', which aims to create plans that are capable to enhance 'swarm behaviour' of the spatial system. This behaviour, learnt from principles in nature, helps the spatial system to increase the overall resilience and lessens the impact of uncertainties, complexity and change. There are two Swarm Planning strategies identified. The first is the introduction of a strategic intervention at a specific location in the system, which influences the self-organisation of the system as a whole in order to become more resilient. The second strategy is to attribute individual spatial components with Complex Adaptive System (CAS)-properties allowing each component to perform self-organisation. Each of the components is emerging freely and self-organises. All elements together will then develop new spatial patterns, which are of higher resiliency than the state of the system before. These Swarm Planning principles are illustrated in a pilot design for a bushfire resilient landscape in Bendigo, Australia. This chapter is published as a book chapter in *Sustainable Energy Landscapes* and as part of the proceedings of SASBE 2012.



Chapter 3
Developing a Planning Theory for Wicked Problems: Swarm Planning

3.1 Introduction

Climate change adaptation is seen as a wicked (VROM-raad 2007; Commonwealth of Australia 2007) or even a superwicked (Lazarus 2009) problem. A wicked problem is accurately defined in the seminal paper of Rittel and Webber: "Dilemmas in a General Theory of Planning" (Rittel and Webber 1973). Wicked problems are defined as being dynamic, they do not know a final solution, are "a one shot operation" and essentially unique. As planners, we do not have the right to be wrong.

Spatial planning is defined in many different ways. Dror for example (1973) describes planning as a process: "Planning is the process of preparing a set of decisions for action in the future, directed at achieving goals by preferable means". In the course of this paper spatial planning is defined as the 'co-ordination, making and mediation of space' (Gunder and Hillier 2009, 4).

Current (and historic) discourses in spatial planning, such as incrementalism (referring to Lindblom 1959), post-positivism (as described in Allmendinger 2002), communicative planning (amongst others: Habermas 1987, 1993; Healey 1997; Innes 2004), agonism (see: (Mouffe 1993, 2005; Hillier 2003; Pløger 2004), reflexive planning (Beck et al. 2003; Lissandrello and Grin 2011) or even the actor network approach (Boelens 2010) do have considerable difficulties to deal with wicked problems, or solutions, or fail to take wicked problems as the subject of planning. Hence, the need for an alternative theory emerges. In this paper this theory, Swarm Planning, is explored and developed.

This chapter is published in the double blind peer reviewed proceedings of SASBE'12 (Smart and Sustainable Build Environments 2012, Sao Paulo, 24–27 June 2012) as Roggema (2012) 'Developing a planning theory for wicked problems: swarm planning' and is, in modified form, published as double peer reviewed book chapter in: Van den Dobbelsteen and Stremke (Eds.), Sustainable energy landscapes. CRC/Taylor and Francis: 'Roggema (2012) Developing a planning theory for wicked problems: swarm planning'.

R. Roggema, *Swarm Planning*, Springer Theses, DOI: 10.1007/978-94-007-7152-9_3,

3.2 Problem Statement

Our world becomes increasingly complex and turbulent (see for instance Ramirez et al. 2008), as reflected in the fields of energy (peak oil and consequences of oil prices (Campbell and Laherrère 1998; Campbell 1999, 2002a, b; Rifkin 2002; Belin 2008; Sergeev et al. 2009), accelerated climate change (Tin 2008; Richardson et al. 2009; PBL et al. 2009; Sommerkorn and Hassol 2009), but also in the global economy. More specifically, climate adaptation, defined as a wicked problem itself, but also energy systems planning (Van Dam and Noorman 2005) are marginally connected with the spatial planning domain. This means that, inevitable, adaptation and energy planning take place in separate world, where they actually are not 'planned' as spatial systems. Meanwhile, regular planning (e.g. (urban) developments) continue to take place.

These problems are wicked and spatial planning lacks the processes, decision-making and tools to uptake them. Thus the problem can be stated as:

(1) Spatial planning is not used as a platform or framework for 'solving' these problems;
(2) Current spatial planning paradigms themselves predominantly focus on decision making within government for a well-described (planning) problem. Within planning theory there is a lack of methods and planning approaches for wicked problems.

While changes increasingly appear in a non-linear fashion, spatial planning increasingly lacks answers.

3.3 Approach

The research presented in this chapter distinguishes several pieces of work (Fig. 3.1).

In Sect. 3.4 a literature review about current planning paradigms is conducted in two different ways. In the first place (Sect. 3.4.1) current paradigms as well as from the past have been identified and analysed on their usefulness for wicked problems. Secondly (Sect. 3.4.2), articles, published in 2010 and 2011 in four international planning journals (Planning Theory, Planning Theory and Practice, Australian Planner and European Planning Studies), were analysed on the merits of containing theories useful to complex problems. This illuminates the common typology of current subjects in planning journals.

In Sect. 3.5, complexity (3.5.1) and planning for cities (Sect. 3.5.2) is explored. On the one hand side because cities or areas are seen as complex adaptive systems (Portugali 2000; Batty 2005; Allen 1996; Dos Santos and Partidáro 2011), but on the other hand the insights from complexity theory could be of use to develop a planning approach capable of dealing with wicked problems. The central question

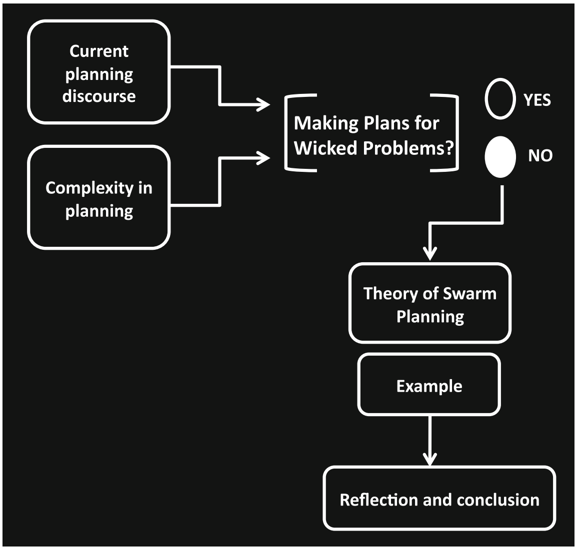


Fig. 3.1 Schematic representation of the research approach

(Sect. 3.5.3) has been if current planning paradigms and/or in combination with scholarly writing on complexity and planning are sufficient of being able to make plans for wicked problems? The answer to this question led to the development of Swarm Planning Theory (Sect. 3.5.4). The theory of swarms (Fisher 2009; Miller 2010) and tipping points (Gladwell 2000), lessons from complexity (amongst others: Schwank, 1965), existing examples of creating plans using the understanding of swarms (Oosterhuis 2006, 2011) and the use of complex adaptive systems properties (Roggema et al., in print) all were used to develop Swarm Planning theory, which enables planning to incorporate wicked problems. This theory has been tested (Sect. 3.5.5) in a concrete design for an area under threat of bushfires: the town of Bendigo in Victoria, Australia.

Finally (Sect. 3.6), the developed theory is critically reflected upon and conclusions were drawn.

3.4 Current Planning Paradigms

In this section a brief overview of spatial planning paradigms is presented. Despite the fact that it is hardly possible to do justice to existing planning theories and paradigms in one paragraph each, it attempts to capture the main characteristics in order to come to a judgement-*light* of the applicability of each to deal with wicked problems. In-depth study and elaboration is required to provide a more thorough basis for the judgements. The current planning paradigm is analysed in two ways. In the first section a selection of well-known paradigms will be briefly described and their eventual shortcomings in the face of dealing with wicked problems will be examined. The second section will look into all articles published in four international planning journals over the years 2010 and 2011.

3.4.1 A Selection of Prevailing Planning Paradigms

In recent planning literature sparse, but strong signals can be found illuminating a change in planning paradigm. Scholars such as Newman, Boelens, Miraftab, Davy and Gunder all, from different angles, point at (the need for) planning 'moving away' from its traditional base: the government. In his pledge for post-anarchistic, or autonomous planning Newman emphasises the power of self-organising groups and organisations, planning for their own environments outside the governmental, political arena and creating herewith a *disordered order* of spaces that are 'becoming' (Newman 2011). In a debate provoking paper Boelens advocates planning to come from 'outside inward', led by actors out of the normal governmental planning arena (Boelens 2010). Miraftab describes the informal, insurgent, planning taking place in slums in South-Africa (Miraftab 2009) and Davy (2008) promotes unsafe planning on order to establish planning without tightening and dictating regulations. Gunder (2011) pledges to step away from the widespread code of what is unconsciously accepted 'good planning', positioning the planner as the one 'who knows', meanwhile, creating, following Davy: a "non-innovative state of mono-rationality". An alternative, which is capable to include wicked problems, looms when the fundamental properties of western planning mono-rationality (Davy 2008) are left behind, being:

(a) *'Playing by the rules'*, which in the case of wicked problems no longer rule;
(b) *'Repeat habitual prior experiences'*, which in wicked problem country is useless, because every time the problem appears to be unique; and
(c) Creating a *'non-innovative status quo'*, which is contra-productive if the wicked problem is 'already changing again'.

According to Davy, mono-rationality must be replaced by an 'unsafe' planning practice of poly-rationality, where liquid, turbulent or even wild boundaries of both planning thought and spatial territory can occur—literally, to do 'it' without the safety of a condom! This is a planning practice that takes risks, accommodates difference and encourages the new and creative.

These planning paradigms, Actor Relational approach (Boelens 2010), Insurgent Planning (Miraftab 2009) and Post-Anarchism (Newman 2011) offer examples of theorising planning and practical real life examples of poly-rationality, showing an increasing un-safety in planning and increasing autonomy in planning processes.

3.4.2 A Review of 2 Years of Planning Journals

The next step in the research is to examine whether unsafe, autonomous and poly-rational theories, concepts and strategies are discussed in the planning community, and if, in relation with the former, wicked problems are addressed. In order to gain insight about to what extent this specific part exists within the spatial planning debate, two volumes of four spatial planning journals have been analysed. The, in total 275 articles, which have been published in 2010–2011 in the Journals of Planning Theory (43), Planning Theory and Practice (34), The Australian Planner (45) and European Planning Studies (153), being the leading theoretical and practice oriented academic planning journals originating from two different continents, have been analysed. The articles were judged on criteria informing whether in the articles theories, concepts and strategies are discussed that potentially can deal with wicked problems. The following criteria have been distinguished:

- Integration (vs. thematic, specific, single subject): a wicked problem cannot be dealt with from a single narrow thematic perspective, because a singular solution for a problem that is wicked enables the problem to evolve into new forms the moment the thematic solution is executed. An integrated approach, in which themes and land-use functions are mutually connected and in which an area is approached as a whole, can deal much easier with unique, new and suddenly changing problems. Does the article approach problems in an integrative way or is it focusing on a specific theme or subject?
- Dynamic (vs. static): a division can be made in the aim of planning to stabilise the future or to emphasise dynamic environments, which need to be planned for and/or even need to be created. When wicked problems are taken into account spatial planning needs to recognise the existence of dynamic, continuous changing spatial settings and configurations. Does the article assume that planning tries to continue the current state or focuses it on dealing with changing environments or subjects?
- Intervention (vs. regulatory): planning can be orientated on arranging general and objective regulations that prohibit or allow certain land-use, or it may aim for a deliberate change. A planning intervention can be realised through design. In general, if problems are wicked they normally are not dealt with by putting regulations in place, as these problems are essentially unique. Does the article discuss a design approach or a planning intervention or does it focus on describing regulations and institutions?
- Paradigm shift (vs. status quo): when problems are new, especially if they are wicked, a new planning paradigm may emerge. The identification of these types of problems at an early stage illuminates their existence in the first place. If so, the early stages of a paradigm shift are announced, even if there are only small rudiments of it visible. In most of the cases however, planning in its current state, a status quo, is described, which is less suitable in dealing with changing circumstances and wicked problems. Does the article describe planning as it is

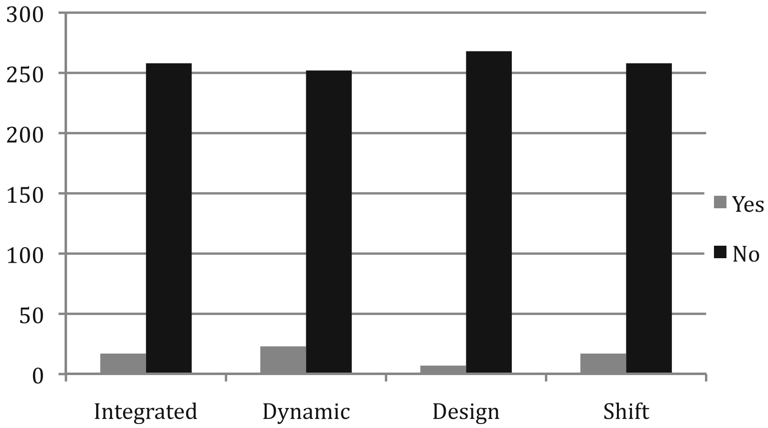


Fig. 3.2 Number of articles in Planning Theory, Planning Theory and Practice, Australian planning and European planning studies (2010–2011) that do and do not reflect integration, dynamics, design and a paradigm shift

currently and/or was in the past or does the article focuses on identifying a paradigm shift?

Having analysed the 275 articles, addressing the question if they contain integrated or thematic, dynamic or stable, interventionist or regulatory and shift or status quo issues, the results are striking and shocking at the same time (Fig. 3.2). The fundamental properties of western planning mono-rationality are still around. Even stronger, articles that address dynamic, integrated, intervention topics and paradigm shifts are hardly found.

The conclusion may be drawn that a very small portion of current planning discourse acknowledges fundamental changes in society, the changes in the environment and the need to plan for wicked problems. However, the current debate is predominantly in the process of raising awareness and describing what is going on. It addresses the necessity to replace old rules for new ones, which can respond to more complex issues and are based on networks, interrelations and connections. There are only a few scholars (e.g. Newman's post-anarchism and Davy's unsafe planning), who discuss the necessity to start planning in a more 'non-linear' way. In this article the search for a planning theory dealing with wicked problems draws upon these scholars and will search where wicked problems are closest related to: complexity theory.

3.5 Exploring Complexity

In order to plan for wicked problems, and more specifically for climate adaptation, we need to take into account that it is likely that climate change will force (step) changes (Jones 2010), that climate change has locality specific characteristics and it requires to bridge impacts occurring over a wide time-range. Therefore, it is useful to explore the potential of complexity theory in three ways. Firstly, we need to understand complex (adaptive) systems, their non-linearity and the idea that small changes might have big impacts, as well as the existence of bifurcation points and tipping points. Secondly, we need to understand cities self-organising systems. And thirdly, we need to build upon the former to make this knowledge available for planning.

3.5.1 Complexity Theory

Many scholars studied the complexity and self-organisation of non-linear dynamic (or adaptive) systems. Amongst these are the works of Prigogine and Stengers (1984), Gleick (1987), Lewin (1993), Mitchell Waldrop (1992), Cohen and Stewart (1994), Kauffman (1995), which are further elaborated and explained by authors such as Johnson (2001), Miller and Page (2007), Johnson (2007) and Northrop (2011). Key concepts from complexity theory, which are seen as useful in a planning context, are the *self-organisation* of complex systems, the surge for an actor to attractors, depicting a *fitness landscape*, the change and transformation of a complex system in times of crisis and the existence of *bifurcation*, 'the point in time where for identical external conditions various possible structures can exist' (Allen 1996) and *tipping points*, 'the point at which the system 'flips' from one state to another' (Gladwell 2000).

Adaptation of (or within) the system is an internal process of *self-organisation*, which is the tendency in complex systems to evolve toward order instead of disorder (Kauffman 1993). The state of equilibrium is called attractor. Complex adaptive systems self-organise and adapt in order to remain within their current attractor. The system only shifts to other attractors (alternative states) after a shock that drives the system out of its current state (e.g. due to significant (or 'step') changes in climate). Major adjustments are needed and after the shock the system will self-organise to achieve those.

The process this system goes through can be represented in the form of a *fitness landscape* (Fig. 3.3) (Mitchell Waldrop 1992; Langton et al. 1992). This fitness landscape includes favourable (the mountaintops) and less favourable (the valleys) positions. A complex system tends to move, while crossing less favourable valleys, to the highest possible position in the landscape, the attractor.

At the mountaintop, the adaptive capacity is highest, which allows the system to adapt more easily to changes in its environment. The pathway of the system is represented in Fig. 3.4. When a system self-organises it strives to reach a higher adaptive capacity by increasing order. When it reaches the mountaintop (B) it will continue to self-organise and increase order. However, by increasing order at this stage, adaptive capacity is decreasing, causing a less stable system (the state of fixed and unchangeable regulations and standards) and starts to move towards a new attractor. At this stage, the system is crossing the valley (from D to E) and

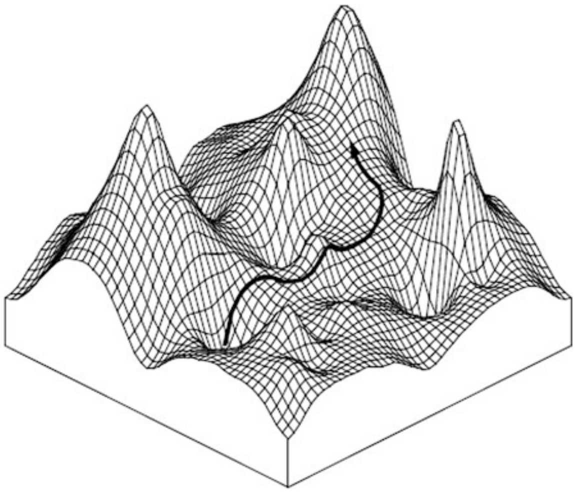


Fig. 3.3 Fitness landscape (Cohen and Stewart 1994) showing a complex system moving from a less favourable to a favourable position or attractor

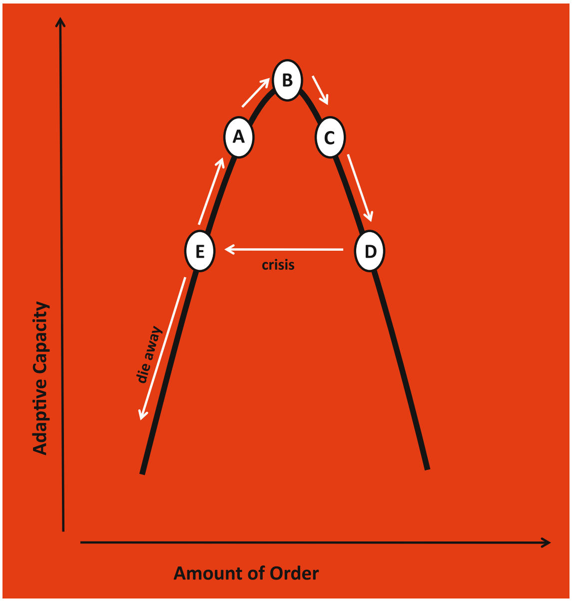


Fig. 3.4 Typical pathway of a complex system towards the mountain top (*B*), evolving towards instability (*D*), and dying or self-organising again (*E*) (Lietaer and Belgin 2007)

searching for a new attractor, which can provide the system with renewed adaptive capacity. After reaching point E (a more chaotic state) two things can happen: the system dies (it didn't reach/find the other attractor) or it self-organises in a new way and starts to build up a transformed system by increasing its order again until it reaches its highest adaptive capacity (the mountaintop) again (B). Point E is defined as the bifurcation point, or: the point where the system fundamentally separates the pathway towards a new equilibrium from the one ending its existence (‘die away’), also known as the tipping point, at which the system ‘flips’ from one state to another (Gladwell 2000).

3.5.2 Cities as Complex Systems

These theoretical concepts have been applied to cities. However, the majority of scholars (Allen 1996; Batty 2005; Portugali 2000, 2006, 2008) use complexity theory mainly to understand self-organising processes in cities through modelling of reality. Modelling remains a central activity at the intersection of complexity and spatial science (O’Sullivan 2004) but there is a growing concern about the implicit limitations of this ‘orientation on modelling’ as the relevance of the links between spatial and complexity theories becomes much wider (O’Sullivan et al. 2006). Still, the main attention in recent academic writings focuses on different kinds of computational representations of spatial analyses (O’Sullivan et al. 2006) and the representation in models through agent-based modelling or cellular automata (Crawford et al. 2005). The question is whether this ‘*mathematicalisation*’ of the city offers more than only an understanding of self-organisation in cities, but merely supports cities in dealing with wicked problems, as it lacks the tools to influence the performance of the city. Spaces (and places) are, as described in Portugali (2006) mainly seen as an object to study, analyse, explain, understand, describe and model…… But this understanding is, to my knowledge, hardly used to inform planning and design processes on how to improve the quality of the city, or to better respond to and prepare for wicked problems.

3.5.3 Use of Complexity in Planning

As a bridge between the understanding of complexity in cities and planning for it, a key set of interrelated concepts that define a complex system (Manson 2001) can be helpful.

At the core the *relationships* between its components and its environment, forming an ever-changing internal structure, determine the whole of the system. Due to the number and complexities of these relationships it is hardly possible to understand or predict the character of the whole system. Because of the wide array of complex internal relationships the system is in most cases able to respond to novel, external, relationships, but in the case there is no internal component capable of responding to novel external circumstances, which are for instance induced through climate change, this may end in a catastrophe for the system.

The system exhibits *emergence*, e.g. the system wide characteristics stem from interactions amongst components (Lansing and Kremer 1993) and are thus much more than a simple addition of components qualities. It is difficult to anticipate change beyond the short term, because other components of the system adjust to the intervention in addition to other changes in the environment (Youssefmir and Huberman 1997). Any single change can have far-reading large-scale effects due to not understanding emergence from complexity (Lansing and Kremer 1993).

A complex system performs *change and evolution* through three different capabilities: (1) self-organisation, e.g. the capability to adjust its internal structures to better interact with a changing environment; (2) Development of a dissipative structure, allowing the system to suddenly cross to a more organised state after being a certain period in a highly unorganised state (Schieve and Allen 1982); and (3) self-organised criticality, allowing the system to keep the balance between nearly collapsing and not doing so, caused by an internal restructuring, almost too rapid to accommodate, but necessary for survival (Scheinkman and Woodford 1994).

Finally, *path dependency* defines the development of a system as ‘a trajectory as function of past states’ (O’Sullivan 2004). This may be true for most systems, Portugali demonstrated that in regards to planning the fact a plan has been released causes a *reverse* form of path dependency in the sense that the trajectory is a function of (not yet realised) future states (Portugali 2008). All of the former properties are found through the study of ecological and, to a lesser extent, economic systems.

The question, however, is whether we can use the knowledge derived from, mainly, ecosystems for artificial systems, such as cities. As demonstrated by Simon (1999), described in Portugali (2006) we can use the findings of natural science to apply in artificial systems, but only to a limited extent. As Portugali demonstrated (2000, 2008) social systems, such as cities and landscapes exhibit a dual complexity: the city as a whole is a complex adaptive system as is each of its parts (Portugali defines them as agents; e.g. human or organisational entities, Portugali 2008). This means that the whole can no longer be explained by the singular behaviour of individual components.

Learning from nature again, most systems performing *swarm behaviour* represent high resiliency, lessening the impact of uncertainties, complexity and change through the development of emerging patterns and structures (Van Ginneken 2009). Swarms (see Fisher 2009; Miller 2010) are self-organising systems in preparing for and responding to changing circumstances, which is, according to Van Ginneken (2009), achieved through (1) the interactions taking place between a large number of similar and free moving ‘agents’, which (2) react autonomous and quick towards one another and their surrounding, resulting in (3) the development of a collective new entity and a coherent larger unity of higher order.

Swarm behaviour can be encouraged through increasing the adjustability of the building by programmatic labelling and tagging of building elements, enabling buildings to customise temporary desires or changing demands (Oosterhuis 2006, 2011).

The above forms the basis for developing the theory of Swarm Planning.

3.5.4 Proposition: Swarm Planning

The objective of this paper is to present the first contours and basic elements of Swarm Planning, which ultimately aims to increase the potential of a landscape or city to deal with wicked problems, such as climate change. Elaborating the above, this means that if the landscape could perform swarm behaviour, it increases its capacity to deal with uncertainty, complexity and change, hence dealing with wicked problems. Therefore, a planning theory that enables swarm behaviour to occur, supports landscapes to reach higher levels of adaptive capacity. This planning theory, Swarm Planning, needs to take at its core the dual complexity of the landscape and therefore to combine complex behaviour of the elements of the system and the complex adaptive behaviour of the system as a whole. And thus, Swarm Planning needs to actively intervene on both levels of the *'dual complex'* landscape.

The intervention

At the level of the whole, an intervention needs to take place in order to start the swarm to behave in the first place. In current theory, tipping points are identified after they have occurred (Gladwell 2000) or identify the patterns that announce these points (Scheffer 2009), but they are not planned. In essence, it describes the process of an evolving system, becoming unstable, ends up in a crisis, 'tips' and transforms through self-organisation to another stable state. However, in the case of climate change, this system change preferably anticipates the actual change. Hence, an early intervention must allow the system to be able to 'flip'. We need to actively intervene in the system to start self-organising processes to anticipate the wicked problem. Hence, this requires an intervention point to get things started.

Obviously, the difficulty is to identify the location, the type and the actor to intervene. As demonstrated elsewhere (Roggema et al., forthcoming) network theory holds the key to identifying the location. The type of intervention cannot be otherwise determined then through the local context (existing landscape combined with specific wicked problem). The actor identifies the point where and the type of intervention. The person or institution most eligible to decide upon this is the problem owner, not necessarily the government.

The freedom to emerge

The second level is the level of the parts (the elements in the landscape). At this level the components of the system need to make use of their joint capabilities to perform as a system as a whole. Only then, the system is able to produce swarm behaviour and achieve a higher adaptive capacity. Therefore, interacting relationships need to be provided with the qualities allowing them to develop emergent properties, to self-organise and to change (Manson 2001). The hypothesis is that if the landscape elements are attributed with the capabilities as described before, they will support swarm behaviour of the whole system. Once the individual components are attributed with these capabilities and free self-organisation will take place, the system will strive for the most optimal stable state (in general: the mountain top in the fitness landscape), which represents the highest adaptive capacity.

This theoretical proposition requires further research on the question how individual landscape elements can be attributed with qualities to allow them to perform emergent behaviour, self-organise and change. The first attempts to answer this question have been undertaken in the work of Oosterhuis (2006, 2011), who attributed swarm characteristics to building elements, and by linking complex adaptive systems properties to landscape entities (Roggema 2011). However, further research is required in this area.

The proposition of Swarm Planning combines directive steering, in the form of an active design intervention (system level), with the freedom of individual landscape elements to shape (and self-organise) the system. The outcome of this process is fundamentally unpredictable, but this does not mean that we cannot be confident that the system, when performing swarm behaviour, reaches a higher adaptive capacity (or in complexity theory: reaches the top of the fitness landscape).

Part of a planning theory must be, in my opinion, besides a theoretical basis as presented above, a practical strategy and practical applications.

The theoretical basis has been used and translated into a practical approach (Roggema et al. 2012a, b) with the five layer strategy as the centrepiece, in which the first two layers identify the point of intervention, layer three arranges and defines the freedom to emerge and layers four and five allow for the individual components to self-organise.

The first practical applications of this theory have also been identified. In the work of Massoud Amin the principle of self-organisation in order to reach higher levels of agility in the energy network (Massoud Amin 2008a, b, 2009; Massoud Amin and Horowitz 2007) can be explained as an early form of Swarm Planning 'avant la lettre'. A second body of knowledge has been developed, designing 'swarm' landscapes for regional climate adaptation (Roggema 2008a, b; Roggema and Van den Dobbelsteen 2008).

3.5.5 Bendigo

Swarm Planning theory has been implicitly used for the design of a bushfire resilient landscape in the Bendigo area. This town, in central Victoria, Australia is surrounded by forest and thus extremely bushfire prone. The town was, amongst several other places in Victoria, hit by the bushfires on Black Saturday, 7 February 2009. Bendigo is one of the fastest growing regional towns in Victoria. It will need to build approximately 23,000 new houses until 2050. At the same time the town is under an increasing threat of bushfires, because (1) the town is surrounded by forests, (2) it is inevitable that new developments will in one way or another enter the surrounding landscape (a push outward) and (3) climate change will exaggerate in the number of hot days and in average high temperatures, leading to an intensified bushfire hazard. In the landscape design for the area (Newman et al. 2011)

Swarm Planning interventions are proposed for the entire system (the whole of Bendigo and surroundings) as well as for specific development locations and individual (landscape) elements.

Intervention at the 'whole'-system level

The major proposition that intervenes in the future development of the entire system is the 'rule' that when a house is destroyed by a bushfire, the house cannot be rebuild but will be replaced by a huge concrete pillar. This pillar symbolises the vulnerability of the place where the house is lost and makes it manifest that the lost house wasn't the most resilient one in the area. Over time only the houses that are best prepared to deal with fire will remain in the area. Because of the fact that the bushfires in this area always originate from the northwest (due to the, on hot days, prevailing hot wind from the central Australian desert), the North Western urban fringe will slowly transform in a zone consisting of the most resilient houses with an increasing number of pillars (Fig. 3.5).

The North Western zone will, after a while, start to function as a shield (Fig. 3.6). The combination and positioning of concrete pillars together will protect the remaining houses from fire attacks from the northwest, because the shield breaks the wind, and thus preventing the fire to continue its devastating pathway, and it also captures embers, which else would function as the outposts of the fire to start new spot fires in front of the fire-front.

The total of the urban 'system' will reorganise itself, because the northwest side of town is prevented from new housing, which therefore takes place at the eastern lee side of attacking fires. As result the city slowly 'moves' towards less vulnerable landscapes in the east (Fig. 3.7), meanwhile protected at its most vulnerable North Western side.

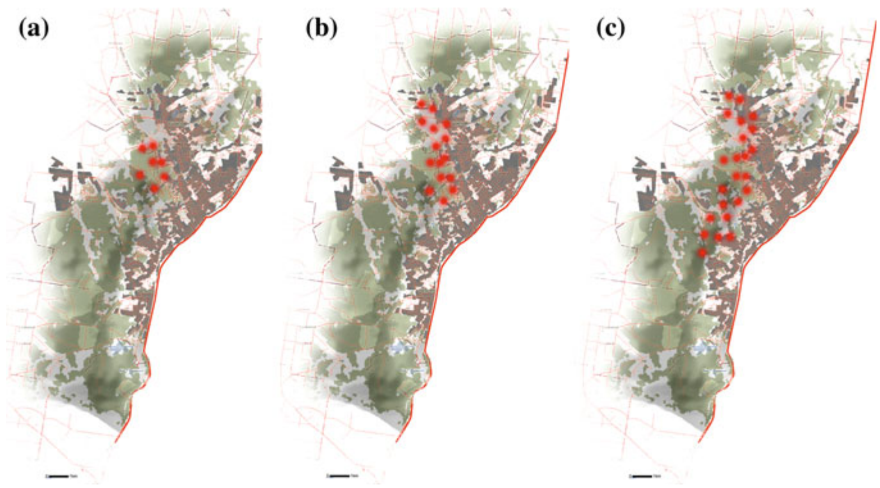


Fig. 3.5 Replacing burnt houses by pillars (the *red dots*): creating safety in the most risky zone (Newman et al. 2011)

Fig. 3.6 Artist impression of the protection zone (Newman et al. 2011)

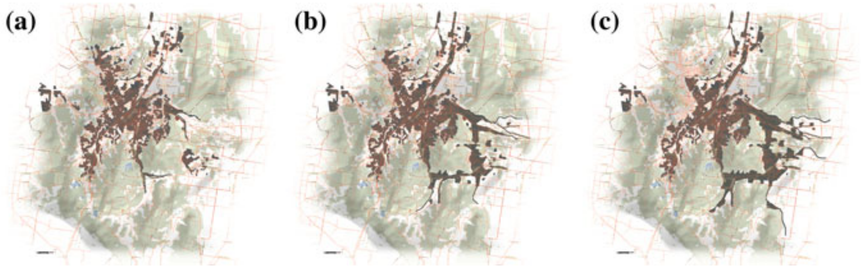


Fig. 3.7 Bendigo 'moves' (Newman et al. 2011)

Freedom to emerge

The city shape at the eastern side can be viewed as the level at which individual landscape components in interaction with each other develop emergent properties. The following landscape elements are determined and attributed with complex systems properties:

- Sand dune: initially the only design intervention that will be realised. The sand is material, which can flow freely in its surroundings, finding shape due to the micro-climatic differences in the specific location. Generally, the sand will form structures according to morphological rules and will ultimately shape as sand-dunes;

- Pillars: once the dunes have formed and reached a more or less stable state the pillars are added in the most strategic spots, namely the places where they have largest sheltering effect. They provide shelter for hot winds from the north and break eventual fire from that direction, but they are also capable of offering shadow, creating a micro-climate where animals and plants can survive during the hottest days;
- Pig face: this is the ‘un-burnable’ plant, which can be planted in order to prevent fire from progressing. The plants are projected at the bottom of the sand dunes and allowed to grow and expand its territory freely. It will, in interaction with the sand dunes and the pillars find its most optimal places to grow. Because it is initially planted at the northern side of the sand-dunes it will stop grassfires from moving up the sand dune hill;
- Bike path: after the dunes, pillars and pig face have established themselves a bike path is added. The path is projected in a way that it profits optimally from the shelter and shadow the sand dunes, pillars and plants offer;
- House: in the last stage of the process people are allowed to build their houses wherever they want to. Because the context is a given, the dunes and pillars created shelter and the bike path accessibility people will generally position their homes (1) behind the shelter, (2) connected to the path and (3) at distance from houses already apparent. This self-organising process will in the end lead to a landscape in which safety, liveability and social responsibility are key values.

Over time the process of growth at the eastern side of town is incremental. As the first dunes are formed and the pillars are under construction, in the next area the dune forming processes can be enhanced. The subsequent process of dune forming, pillar building, planting and occupation leads to a slow occupation and transformation of the landscape (Fig. 3.8), allowing it to adapt to the changing circumstances in an easy way.

The design for Bendigo can be seen as an example of Swarm Planning, in which the core characteristics of complexity are used to intervene in the system and start a process leading to a higher adaptive capacity. It can also be positioned in the tradition of planning history. The design represents elements of reflexive planning, in the sense that it incorporates uncertainty of the future and emphasises a collective focus on change and alternative futures, but it also contains elements of insurgent and post-anarchist planning, in the sense that the design allows for spontaneous, unregulated planning undertaken by the people that eventually will occupy the landscape. The only point where it clearly deviates from these planning paradigms is the firm decision about the proposed intervention, the inability to rebuild after burning (and replacement by a concrete pillar) as well as the initial sand suppletion in the eastern fringe.

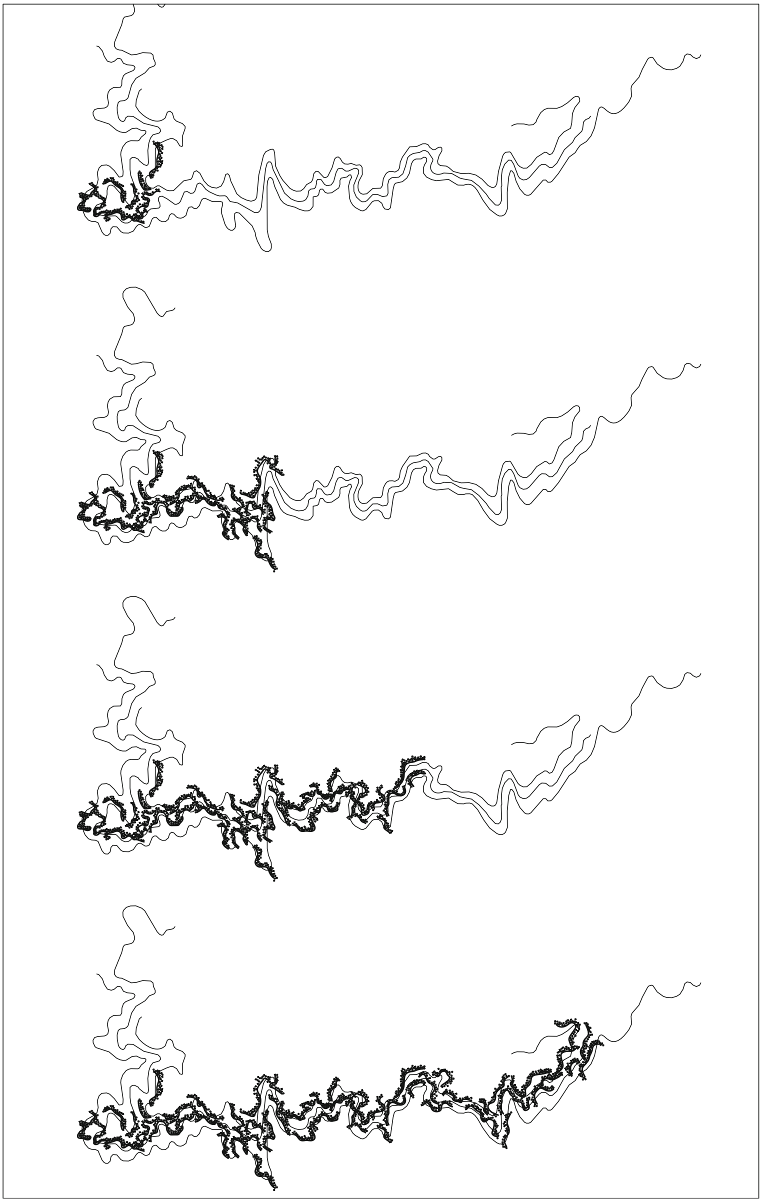


Fig. 3.8 Intervention, followed by occupation in subsequent steps (Newman et al. 2011)

3.6 Conclusion

In this paper it has been demonstrated that current planning discourses are strongly focused on the government as major actor and rely mainly on existing rules, regulations and established procedures. Moreover, the academic debate, as represented in four international planning journals illuminates the scarcity of articles focusing on strategies and practices, which focus on interventions, incorporate a changing and dynamic future and emphasise a paradigm shift. This illuminates a gap in planning practice and theory. This gap will lead to suboptimal preparation for climate change impacts, both in adaptation and in energy supply. This may be seen as very risk-full, because, even if decision-makers should decide that climate change impacts need to become part of planning practice immediately, it will take a shift in the planning frameworks, which in itself takes amounts of time. This time lag might imply that is becomes too late to implement the required changes on time.

Complexity theory might open the opportunity to integrate the characteristics of wicked problems in spatial planning and as demonstrated in this article has been subject of debate to link complexity and city and geography, but unfortunately complexity theory is mainly used in a mathematical, modelling way to better understand self-organising processes in cities and not to identify design interventions or plans to increase the capability of cities (and landscapes) to prepare for the impacts of wicked problems (e.g. climate change). This leads to suboptimal preparation of communities in those cities and landscapes.

Therefore, in this article a proposition is launched to develop a planning approach, which can integrate complexity theory and uses it for planning and design purposes. Named 'Swarm Planning' is an attempt to do so and, learning from the fact that cities have been attributed with a dual complexity (Portugali 2000), it identifies two major levels of intervention: the whole system, a level at which a strategic intervention is required, and the level of the individual components, to which the properties of complex adaptive systems need to be attributed in order to allow free emergence. Both levels in conjunction are able to perform swarm behaviour, which improves resiliency through lessening the impact of uncertainties, complexity and change.

Compared with the way planning is practiced in many institutions, thinking in points enforcing change and free emergence, is the opposite of current practice. Generally, tipping points are not sought, but comprehensive developments are seen as the interventions and these comprehensive interventions are planned in great detail and for entire areas, not allowing them to develop freely. The aversion against tipping points, and surprises, and the willing to paternalise the entire planning process, including its detailed execution, is grounded in the political culture in many countries where risk has to be avoided and uncertainties or 'uncontrollabilities' must be abandoned. However, pursuing the existing (and historical) path-dependent political pathways will lead to 'more of the same' policy, which, and this is for certain, will not produce the planning interventions that are required to deal with the wicked problem of climate change.

And it is true, the results of Swarm Planning are, partly, unpredictable and this is, especially to the responsible decision-makers a danger, but it is also a *conditio sine qua non*. Because in Swarm Planning the new state of the system is undefined, and not possible to define either, there always is the danger of ending up with the wrong outcome, but continuing on the same pathway of not adjusting will end in repetition of history and this will certainly not bring the answers to fundamental different problems of the future. Having said this, there is a lack of understanding of what the future system, planned through Swarm Planning, may be, and more research can be carried out in this field. However, given the unpredictability future state of complex adaptive systems it can be questioned whether more understanding will shine brighter lights on the actual future of the system.

This leaves alone the potential of Swarm Planning to be used in landscape (and city) design. As the example design demonstrates it is very well possible to design a landscape by making use of dynamic and complex principles. Moreover, it illuminates the potential for a community to slightly move towards an adapted and safe state and at the same time to pursue their own desires in realising a future safe and resilient living environment. As this is only the first, implicit, design, the approach deserves further testing and application.

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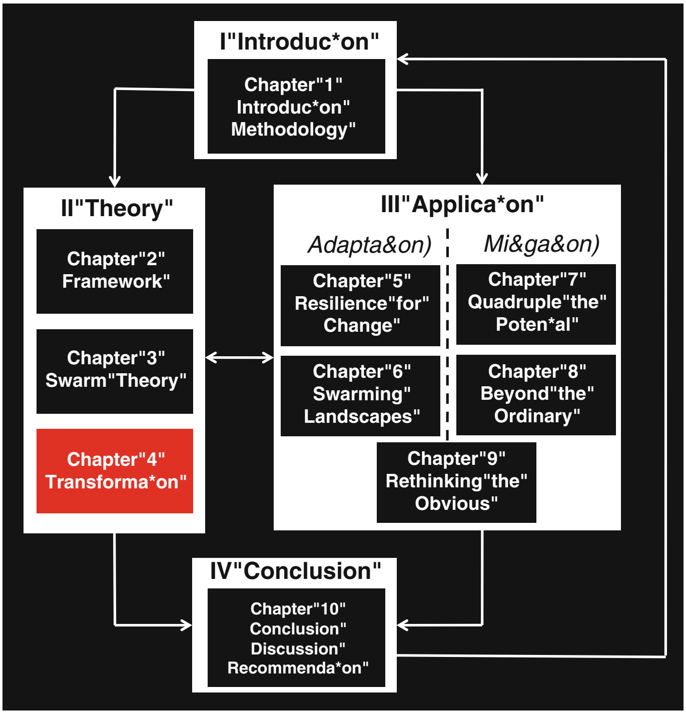
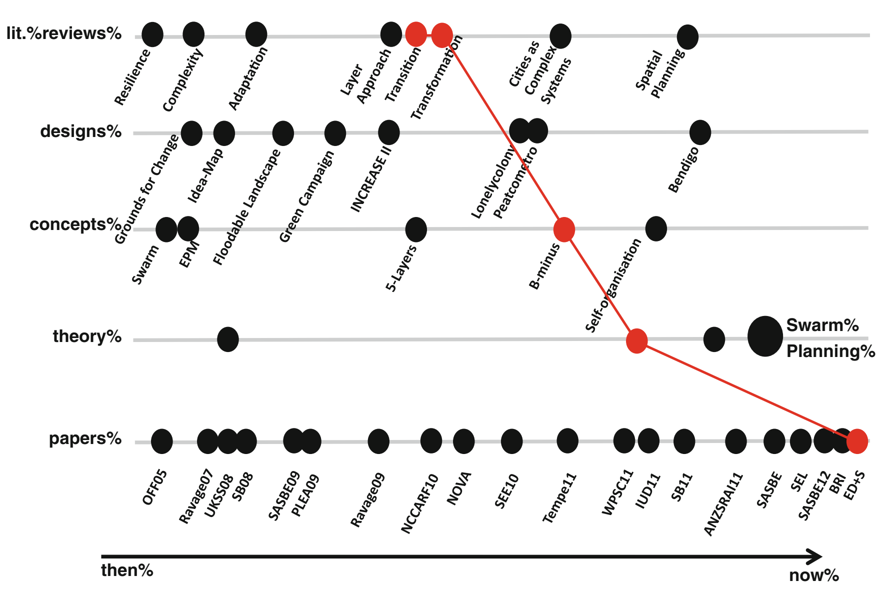
The Bridge: Three–Four



When dealing with the wicked character of climate change the future is only to a certain extent predictable. The majority of spatial planning is emphasising moderate and slow change, if at all. The basic driver for much spatial planning lies in safeguarding existing interests and therefore unchanged spatial configurations and a functional order. Under influence of climate change this aim not to change is under threat, because future change may require serious changes in the spatial organisation. Moreover, when the principles of Swarm Planning, both the framework of Chap. 2 as the theory in this chapter, are used to design spatial plans for the future, the dynamic character that is incorporated in Swarm Planning requires the possibility to change the system, sometimes fundamentally. In this chapter several ways a spatial system can navigate change are compared: incremental change, transition and transformation. It is concluded that, when fundamental shifts are required in the spatial system both incremental change as transition pathways shortfall in achieving that aim. Incremental change is seen as a slow process, which modifies the landscape only slightly. Transition is seen as a fluent change towards a new future, which is an improved version of the existing. Only transformation is seen as a way to change the system fundamentally enough to deal with the more serious impacts of climate change. Transformation is seen as a change towards a future that is fundamentally different from the existing. Therefore, in this chapter transformation is theoretically further elaborated. Framing the change as a transformation from one system to the next system of higher complexity illuminates that the new system, although not yet visible, is already apparent while the existing system still fully operates. The predecessors of the new system (called B in this article) already exist. These ‘B-minuses’ of the new system are found in two ways: as early warning signals, hidden, but currently existing, or they can be created. In order to identify the locations in the system where to create these ‘announcers of change’, network analysis is used. Where the most intense and connective nodes are located, the most successful ‘B-minuses’ can be created, e.g. where a system change is most likely to start. As illustrated in the case-study design for the Peat Colonies, these principles are able to guide the design of a climate proof landscape. This article/chapter is/will be published in the Journal of Environment, Development and Sustainability.



Chapter 4
Incremental Change, Transition or Transformation? Optimising Change Pathways for Climate Adaptation in Spatial Planning

4.1 Introduction

In recent works different scholars characterise the current timeframe as turbulent and instable. The Earth system is being pushed outside its ‘Holocene range’ into the ‘Antropocene’ (Steffen et al. 2004), there is a looming crisis, which both causes and decreases the solvability of increasing instability (Walker et al. 2009). We live in a timeframe of a rapid change, uncertainty (Chapin et al. 2009) and turbulence (Ramirez et al. 2008), defined as: “the dynamic properties arise not simply from the interaction of the component organisations, but also from the ground itself. The ‘ground’ is in motion” (Emery and Trist 1965).

These kinds of typecasts pose ‘the greatest challenge for research and policy ever to confront humanity’ (Steffen et al. 2007), major changes of current systems are necessary (Olsson 2011) and as a consequence, there is a need for novel and adaptive governance approaches at the global, regional and local scale (Dietz et al. 2003; Folke et al. 2005; Berkman and Young 2009).

Regarding climate change, and beyond ‘solving’ the climate crisis, adaptation of our societies is necessary and a broad spectrum of adaptation types, such as regulations, financing, adjusted procedures, as well as in spatial planning is required. Adaptation to climate change implies change from the current to an adapted situation. This change can occur in different ways: gradual and incremental, through a transition or in the form of a transformation. This chapter will examine the different possibilities to enhance the required change, develops a preferred pathway and applies this pathway in a case study.

This chapter is published in *Sustainability*: Roggema et al. (2012).

R. Roggema, *Swarm Planning*, Springer Theses, DOI: 10.1007/978-94-007-7152-9_4,

4.2 Research Approach

4.2.1 Research Context

In most Western societies the political-administrative system claims the power over decision-making in spatial planning issues. The majority of these decisions focus on, but are not limited to, the shorter term and tame problems (Conklin 2001). This implies that change is incremental and at slower paces. However, if problems are wicked (Rittel and Webber 1973), such as for instance climate change (Australian Government 2007; VROM-raad 2007; Lazarus 2009), other types of change are required. These wicked problems may cause events occurring which are unprecedented and surprising. An incremental change in the spatial lay out of an area is then not fast enough to deal with the consequences or anticipate these unpredictable events. In this chapter these types of change are formulated as pathways towards a new spatial system (e.g. lay-out) that is capable of accommodating these unforeseen future events and impacts. A pathway is in the context of this chapter seen as a way towards this new spatial system for specific wicked issues, in this case climate change. Hence it is not a general pathway that needs to be applied for an entire society or for all aspects within a society. There are still many aspects and spatial elements that will function very well while undergoing incremental changes. The pathways that describe change in a different way are transition and transformational pathways. Decision makers, e.g. politicians in the political administrative system, have the ability to decide to choose the appropriate instruments and tools to achieve these transition and transformational pathways, but only for those issues that require those kinds of transitional or transformational change (e.g. wicked problems). In spatial planning terms these instruments and tools go beyond the traditional zoning plans, which mainly enforce incremental changes. Other instruments, capable of initiating change, are required. Examples of these more incentive based instruments are financial, regulatory or spatial interventions. These function as the signals (early warning or created) that will be discussed in paragraph six. After implementing these incentive based instruments and tools they can become, spatially translated and designed, part of the regular zoning plans.

This chapter focuses on specific elements of society. It emphasises the relationship between the more severe and unexpected impacts of climate change and the way these impacts can be dealt with through spatial planning. The question answered is how our spatial layout can be adjusted in a way that it can become more adjustable, anticipative and prepared for unexpected change. Our planning processes need to aim to define the future spatial system that is capable of accommodating these future impacts. This requires change in a more fundamental way than current planning can do. As mentioned, this chapter focuses on the impacts of climate change. However, other wicked problems or significant change can be dealt with using the same methodology. Demographic developments and also economic change usually change in a more predictable way. Change in the population, except maybe for migration, can be very well predicted and economic change, except for the Global Financial Crisis, is well planned for and predictable, in Western countries for instance at a development pace of around two per cent. The art of anticipation must therefore focus of these unpredictable aspects of the demographic and economic change and it needs to identify the 'announcers', the *B-minus*es (see para 5) of change.

4.2.2 Problem Statement

Climate change will impact our spatial layout. Severe and unpredictable events, such as floods, cyclones, droughts or bushfires impact the places where and the way we live. Climate change is, as mentioned before, seen as a wicked problem, causing unexpected, uncertain and unprecedented impacts and events. In the context of this chapter the focus lies on events that come as a surprise and are categorised as the more severe hazards. The more predictable impacts of climate change can be dealt with in regular planning processes, as they only require minor and incremental changes in the spatial layout. This implies change, ranging from small adjustments to fundamental adaptation. Because these impacts can happen at very short notice, but may also take decades to develop it is important to be 'always prepared'. In order to accommodate these changes in spatial planning, spatial transformations need to be implemented. Current spatial planning practice is very well equipped to accommodate incremental change and in some examples transitions, but is badly prepared for transformations. At a certain time dimension it is easy to enforce change, such as in periods when an area undergoes urban developments, or when large reclamations, peat depletions or land consolidations take place in rural landscapes. After these changes have taken place the spatial patterns remain unchanged for many years.

In the Dutch context, most of the land use in the countryside is fixed, supported as it is by land use planning, which ensures in most situations unchanged use for the occupants. Only in case of national importance (such as railway lines, major infrastructure or national safety) the national government can enforce changes. In this context adaptation of spatial patterns is difficult.

4.2.3 Research Objective and Approach

The objective in this research article is to identify possible pathways that might enable spatial adaptation and develop and test the most suitable theoretical approach. The research question is therefore the following: What is the most optimal 'change' pathway, enhancing adaptation to climate change in spatial planning? In order to research this question the object of spatial planning is seen as a complex spatial system, which has the features and characteristics of complex adaptive systems. Changes in these systems follow the rules of complexity and this is the reason why transitional and transformational pathways are the focus. These pathways have the ability to increase the adaptive capacity of (spatial) systems and thus improve the anticipative qualities in spatial systems. The research approach is both deductive and inductive. As deductive research approaches emphasise the general theory is developed first, before validation in the form of a (or several) case study is executed. The theoretical concepts of transition and transformation have been explored before the Peat Colony case study was undertaken. However, while elaborating the case study, further theorising took place and the concepts of networks, *B-minus*es and interventions were developed.

The following five distinctive steps (Fig. 4.1) are distinguished:

1. Analysis of existing change concepts (Sect. 4.3);
2. Comparison of change concepts (Sect. 4.4);
3. Further concept development of the preferred concept. The applied method to intensify theorising, were the so-called pizza debates. These debates consisted of small group sessions providing an iterative process of consecutive brainstorm → capture → writing → brainstorm → elaboration → capture → writing (Sect. 4.5);
4. Spatial identification of key change elements: (1) Early warning signals and (2) Creation of starting points of transformation (Sect. 4.6);
5. Application of the theoretical concept in a case study (Sect. 4.7).

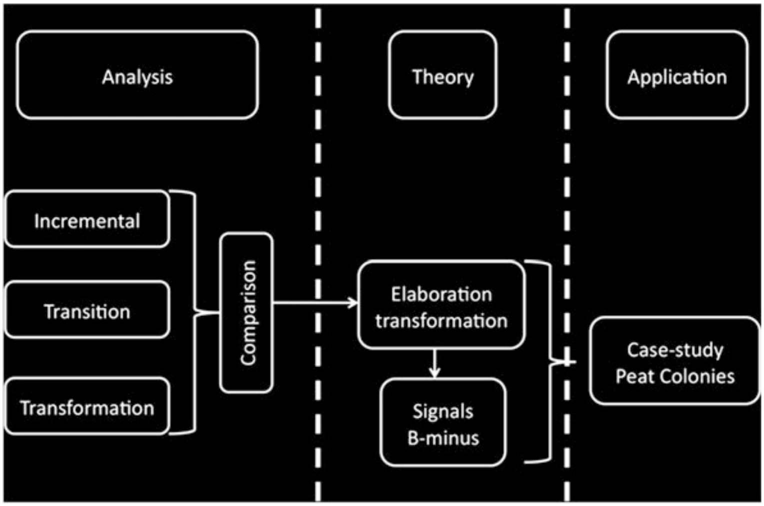


Fig. 4.1 Schematic overview of the research process

4.3 Analysis of Change Processes

In this section three possible change concepts are analysed: incremental change, transition and transformation. There are many ways change can be looked at. Change can happen independently from actors ('it just occurs'), it can take place as a response or reaction on a certain event (this reactive change is in line with incremental changes) or change is pro-active and anticipating the future, which links more with transitional and transformational change as discussed in this chapter.

4.3.1 Incremental Change

When the three most recent regional plans for the province of Groningen (Provincie Groningen 2000, 2006, 2009) are analysed, changes both in the aims and policies as well as in accompanying functional maps are marginal. Once policies have been defined in the initial plan, they are to a large extent repeated in subsequent plans. When the respective functional maps are measured the repetitive character becomes clear: approximately 2 % of the land area is permitted to change its function over the effective term of the three plans (e.g. 13 years). Despite the fact that there are numerous natural or societal changes occurring in the same spatial area, the spatial planning options to change functions or land-use in the next 10 years after a regional plan is adopted, are limited to only 2 % of the area. The Groningen example highlights the 'incrementality' of change and is even more appalling when compared with a preliminary climate adaptive design made for Groningen province, in which approximately 30 % of the land area potentially needs to undergo a functional change (Roggema 2007). These incremental changes are visualised as a straight but slowly rising line along which the consecutive plans are positioned (Fig. 4.2).

Current planning allows plans to evolve from A to *A-apostrophe*, while the major changes required emphasise a shift towards B (Fig. 4.2).

4.3.2 Transition

A transition is defined as 'a gradual, continuous process of societal change, changing the character of society (or a complex part) structurally' (Rotmans et al. 2000). De Roo (2008) attributes dynamics to this change: between two stable phases a dynamic phase enables the system to shift from an old (weak) context towards a new (stronger) one. Various studies on change management demonstrate that this change can only take place if a crisis has been experienced (Zuijderhoudt 2007;

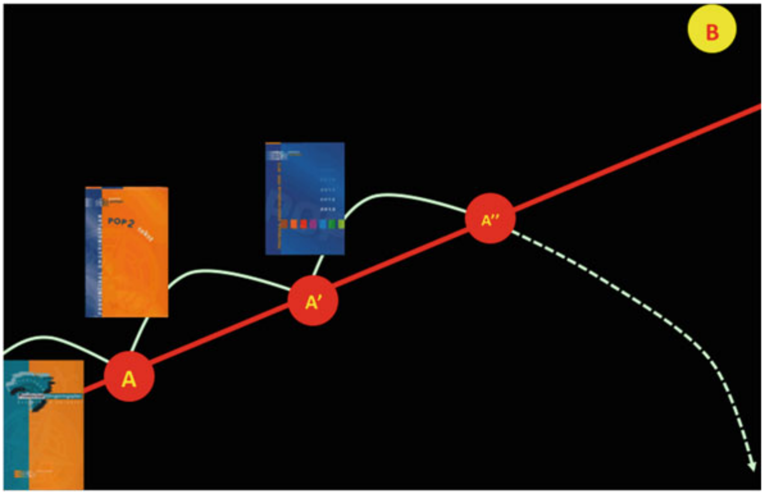


Fig. 4.2 Subsequent waves of plans of the same 'family'

Hurst 1997; Peters and Wetzels 1997; Homan 2005). Corresponding schemes all describe this transition as a fluent line up to a certain point where chaotic circumstances appear. Out of this chaos a new fluent line emerges. The fluency of the transition implies that the system itself is not fundamentally transformed. After the transition the same system has reached a new stable state of a higher complexity or quality.

4.3.3 *Transformation*

Transformation trajectories are the subject of a growing body of literature (Gunderson and Holling 2002; Geels and Kemp 2006; Chapin et al. 2010). Folke and colleagues (2010) describe a transformation as 'the capacity to transform the stability landscape itself in order to become a different kind of system, to create a fundamentally new system when ecological, economic, or social structures make the existing system untenable'. Transformation is divided in three phases: preparing, navigating and stabilising (Chapin et al. 2009; Olsson 2011; Olsson et al. 2006). The moment between preparing and navigating transformation is defined as the window of opportunity, where 'the presence of many options a sequence of events yet a short time-frame leading to the start of a transformation'. This process is called transformation, but it can be questioned if the change described is (limited to) a change of direction within one system instead of a transformation of one system into fundamentally other. Alternatively, transformation is described as

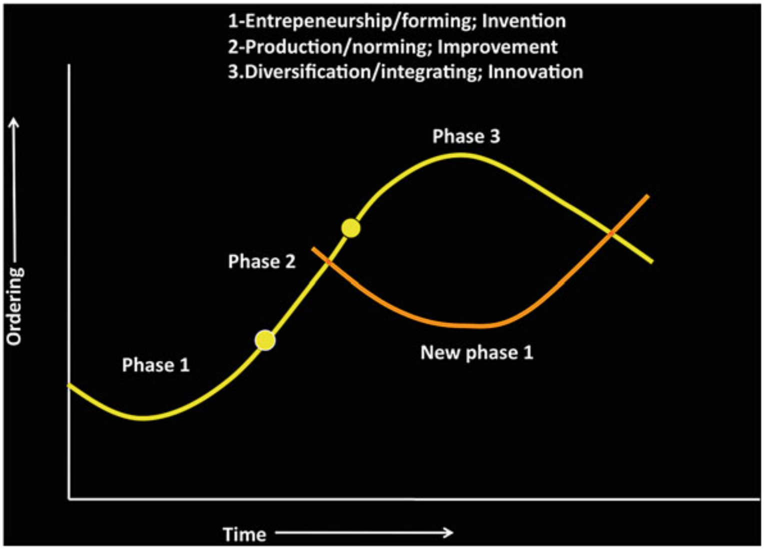


Fig. 4.3 Overlapping growth cycles (after: Ainsworth-Lands 1986)

disconnected processes of growth ((Perez 2002), cited in Blauwhof and Verbaan (2009) and Ainsworth-Lands (1986)): The next 'forming' cycle (phase 1) already starts while the previous 'integrating' stage (phase 3) is still ongoing (Fig. 4.3) (Ainsworth-Lands 1986).

This new forming phase, interfering the existing growth cycle or regime, is initiated through niche innovations, one of the levels that are part of the multi-level perspective (Geels 2002, 2005, 2011). The multi-level perspective consists of three analytical levels: niches (the locus of radical innovations), socio-technical regimes (the locus of established practices and associated rules that stabilise existing systems) and the exogenous socio-technical landscape, representing the nearly unchangeable values and biophysical features. Change starts in niches, where novel configurations appear (Geels 2002). The effectiveness of the change, e.g. whether a regime shift (or transformation) will occur, is determined by reinforcements at the regime and/or the landscape level (Kemp et al. 2001). Hence, this reinforcement determines whether a novelty fails, modifies the regime or transforms the landscape.

The process of transformation consists of several elements (Fig. 4.4). The existing regime is dynamically stable (point 2), which means that it is potentially open for change. However, it will only open up if the pressure from the landscape level creates a window of opportunity (point 1). Both levels then influence externally the niches (points 3, 4), which supports the development of novelties (point 5). Once these novelties are developed and are aligned towards a dominant

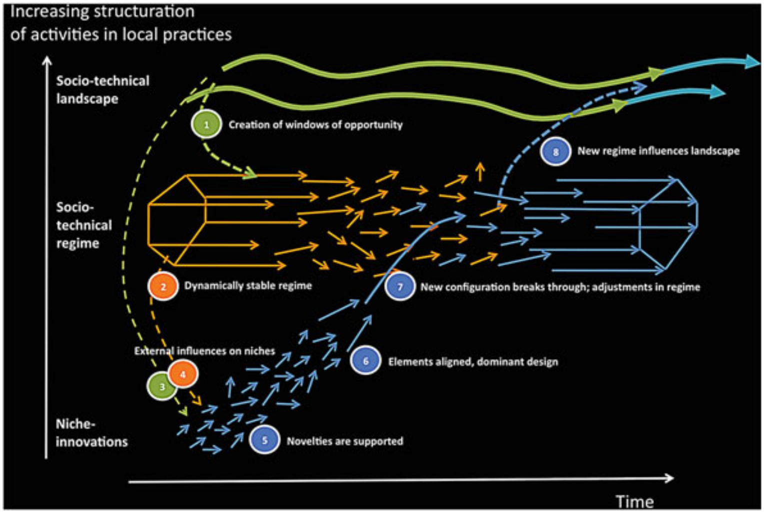


Fig. 4.4 Interaction between the levels of the multi-level perspective (after: Geels 2002, 2005, 2011)

design (point 6), they are capable of breaking through the existing regime (point 7) and enforce adjustments to the old regime, which then will transform into a new regime. Eventually, when the regime shifts are profound, they may influence the landscape level, changing the set of values and/or biophysical properties (point 8).

4.4 Comparison

4.4.1 Criteria

The extent to which the processes of change can be used to describe, or enhance, fundamental shifts, depends on the level the following criteria are met:

1. The extent to which the process of change enhances adaptation to climate change in spatial planning;
2. The suitability of describing fundamental change: e.g. a shift from one system to another?
3. The appropriateness to define and achieve a long-term future?

These criteria can be used to review the processes of change and estimate their suitability in enhancing climate adaptation in spatial planning.

4.4.2 Comparison

In order to compare the three pathways of change they are judged against the criteria mentioned above.

(a) Enhancing adaptation in spatial planning. All three pathways can enhance climate adaptation in spatial planning. However, incremental change does offer the least potential to do so, because this process leans most to existing habits, decision-making and current policies. Hence, in spatial planning changes are less elaborated and the spatial patterns are to a large extent similar to what had been realised in recent history. The transition pathway aims to change from a current state of the system to a future, climate adaptive, one. Hence it offers a good pathway to enhance climate adaptation. It depends on the magnitude of required change if transition pathways are suitable enough to reach this required change. When the change is expected to be more rigorous, the existing system needs to be able to transform into another, better equipped system. In that case, the transformation pathway is more suitable;
(b) Fundamental change. When a serious change is expected to happen, or is required to meet future change, the existing spatial patterns must be able to transform in something new that is capable of dealing with those changes and become resilient. A transformational pathway, implying systems change, seems to be the most likely pathway to be satisfying, because this process aims to change existing patterns in something else, becoming prepared for the new demands. To a lesser extent transition pathways allow for change, but in less fundamental ways as the system remains the same while transitioning to a better version. Incremental change is the least suitable process, as it focuses on little changes that are in general not fundamental;
(c) Long-term future. Incremental change, transitions and transformations offer the possibility to identify long-term desired futures. In many of the regular spatial plans, focusing on incremental change, such a long-term perspective is defined. However, in the wake of all kinds of practicalities this ambitious future becomes out of sight as soon as practical political decisions need to be made. In transitional as well as transformational processes this long-term desired future is conditional. Without a sound idea about a desired future, transition and transformation are not useful, because it is unclear where to aim for. The difference between the two relates back to the second criterion: when change is more fundamental, transformation seems to be more suitable.

Based on these criteria a transformational process offers better prerequisites to deal with and achieve more fundamental changes. Many judge estimated climate change as uncertain and assuming future change can become more profound than predicted spatial patterns need to be capable of changing more fundamentally. Therefore, the transformational process will be more elaborately discussed in the following section.

4.5 Theorising Transformation

Assuming that fundamental changes will occur in the future the spatial patterns need to be capable of changing accordingly. Current spatial planning practice, as illustrated before, does, in this regard, not satisfy. The changes that are possible in current plans are too small to allow fundamental change. These kinds of change are only possible after a period of stability, in which satisfaction with current paradigms was dominant. During this period repetitive spatial plans are improved, but remain versions of the same type: they shift from A (the original) towards *A-apostrophe* and *A-double apostrophe*. Often, this cycle ends when a political cycle comes to a close. A transformation to B, when a fundamental new type of spatial plan can be conceived, is only possible after ending the cycle and the desired long-term future cannot be reached within the current period (Fig. 4.5).

Therefore, a transformational process better suits change from a current series of spatial plans (A) into a fundamental new configuration (B). As Geels indicates, transformation originates somewhere outside the existing regime while the current system is still operating. The start of the 'forming' phase of the growth curve of the new system happens where niche innovations are located. The forming of system B can only take place through novelty development, disconnected from the current stable regime (Fig. 4.6). This system needs to follow its own growth curve of forming, whilst crossing and overtaking the current system when it still operates in its norming and integrating phases. Here, we call the forming phase of the new system (B), *B-minus*.

B-minus can be reached after a disaster or after a prolonged period of unchanged regime. In both cases transformation is supported when an attractive long-term future is defined. Icons and identity (Castells 1996), branding (Franzen

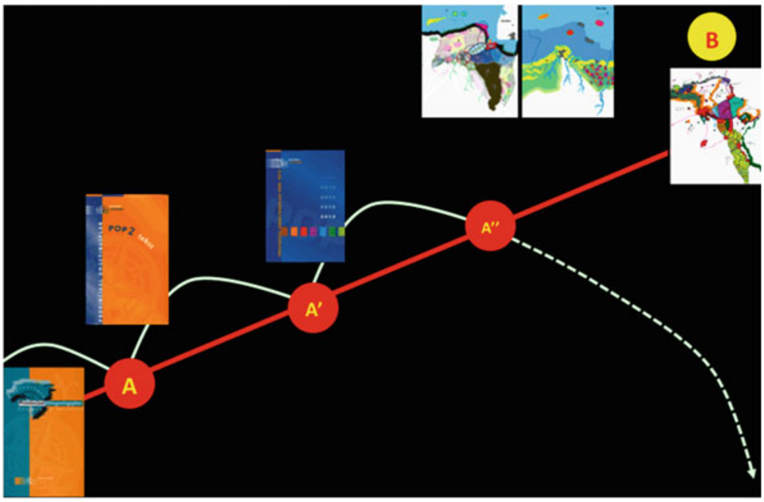


Fig. 4.5 The desired future system defined and 'missed' by consecutive regional plans

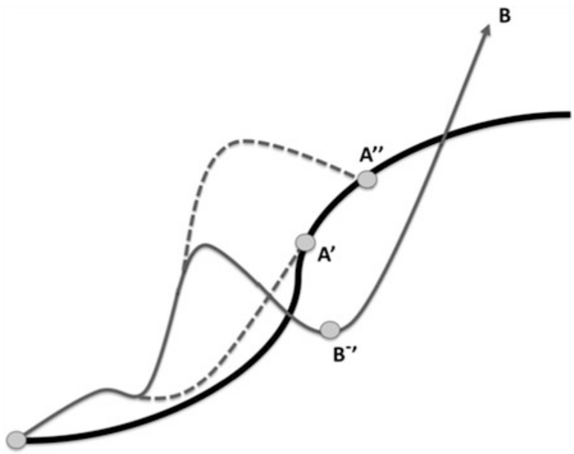


Fig. 4.6 The fluent line of transition changes *A* in *A-apostrophe*, while the shift to *B* requires a discontinuous process through *B-minus*

and Bouwman 1999; Roberts 2006), branding identity (Ghodeswar 2008), or a stickiness factor (Gladwell 2000) can play an important role in making the future vision attractive. This attractive new future can only be reached through dynamic planning, as described for climate adaptation by Berger and Chambwera (2010). Only then, high expenses and existing standards can be overcome.

A disaster requiring immediate action disturbs regular policies as these become instantly no longer relevant. An instant a shift from one pathway to another is likely (Fig. 4.7). Hardly visible to regular policy-making, pathway B was already in operation (*B-minus*) but becomes suddenly interesting, as it enables pathways to recover and provides solutions for the longer term.

The other situation in which opportunities can be found to shift pathways to a new desired system is when a current system slowly fades away, for instance because it does not meet current (political) demands anymore. At a certain point another system takes over (Fig. 4.8), because the new system (B) contains features the current timeframe demands.

The change from the current (A) towards a new system (B) requires a shift in its initial stage, e.g. the pre-phase of B: ‘*B-minus*’ (Fig. 4.9). This rudimentary, or ‘forming’ stage of the new system B contains elements of the new system already, but is far from complete.

In order to anticipate a transformation it is important to recognise or create these predecessors of B. This will be discussed in the following section.

4.6 Signals

Once the attractive future system is defined, it is possible to look for elements of *B-minus*. When a window of opportunity (Olsson et al. 2006) occurs transformation is likely to start and *B-minus* elements become visible. There are two ways to distinguish the elements of *B-minus*:

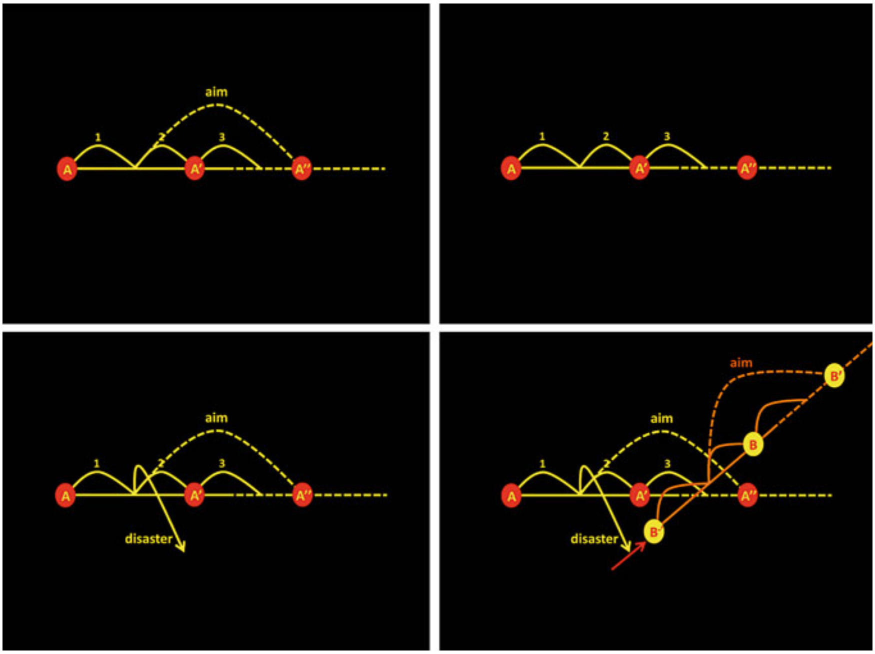


Fig. 4.7 After a disaster pathway *B* takes over

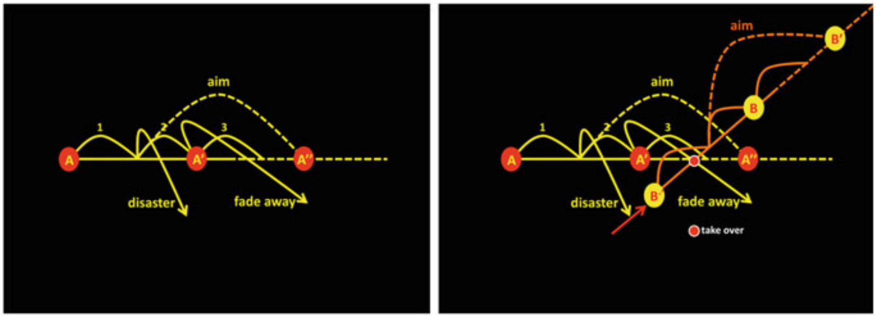


Fig. 4.8 System *A* fades away and *B* takes over

1. Observation or active search for signals announcing a transformation, so-called early warning signals (Scheffer et al. 2009);
2. The active creation of harbingers of a transformation.

This distinction is used to identify the signals that are apparent or can be developed in a certain context and especially the stronger signals, or outliers, that instigate the start of changes. In planning and deciding on a pathway to a future spatial system, this distinction is not relevant, because every trigger that may start a change is valuable as catalyst of the process.

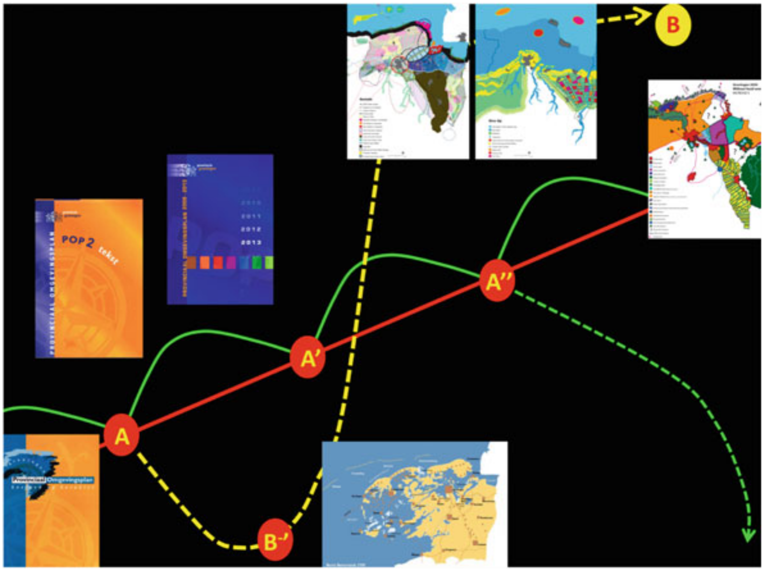


Fig. 4.9 Towards *B* via *B-minus*

4.6.1 Early Warning

In the work of Scheffer et al. (2009), early warning signals are defined for systems approaching a major change. Despite the fact that it is very difficult to develop accurate models to predict thresholds in most complex systems, Scheffer and colleagues discuss the generic character of early warning signals from a range of complex systems. They conclude: ‘if we have reasons to suspect the possibility of a critical transition, early-warning signals may be a significant step forward when it comes to judging whether the probability of such an event is increasing’. They distinguish the following signals:

1. Critical slowing down: The intrinsic rates of change in the system decrease, leading to a system state that more and more resembles its past state. Two symptoms are distinguished: increase of autocorrelation and increase of variance.
2. Skewness: An unstable equilibrium, which marks the border of the basin of attraction, approaches the attractor from one side. In the vicinity of this unstable point the rates of change are lower. As a result, the system will tend to stay in the vicinity of the unstable point relatively longer.
3. Flickering: The system moves back and forth between the basins of attraction of two alternative attractors.

Table 4.1 Translation of early warning signals into spatial dimensions

Announcement of system change (early warning signals, derived from (Scheffer et al. 2009))	Possible translation into spatial dimensions
Critical slowing down (increase of autocorrelation, increase of variance)	Maintaining old historic structures, re-emphasise existing patterns of functions Repetitive policies (the longer policies remain unchanged or are repeated over and over again, the closer we are to a system change)
Skewness	Dominance of one centre over another, core-periphery
Flickering	Temporarily repetitive occupation for living, temporarily repetitive flooding
1. Scale-invariant distributions of patch sizes/ increased spatial coherence 2. Increase of regular patterns	Urban sprawl, repetitive urban patterns/building blocks

4. Types of spatial patterns: (1) scale-invariant distributions of patch sizes and increased spatial coherence, or (2) the appearance of regular patterns in systems governed by local disturbances.

These signals not necessarily contain a spatial dimension or make them easy to use or understand in a spatial planning context. However, Table 4.1 shows a first attempt to 'translate' these signals into possible spatial planning dimensions. No research that we know of aims to unfold early warning signals, announcing a system change, in the spatial domain.

4.6.2 Creation

Besides trying to identify early warning signals, another option is to actively create starting-points for systems change. Points in networks where developments are likely to start can function as the elements of *B-minus*. Network theory emphasises that some nodes in networks are more suited for the ignition of change than others. The following key characteristics of networks are derived from Newman et al. (2006):

1. Once enough edges are added, properties of the network suddenly increase in quality (Erdós and Rényi 1960);
2. Directed networks consist of a core (a giant, strongly connected component), links-in and links-out, as well as other islands and tendrils, represented visually by Broder et al. (2000) as a bow-tie;
3. The small world effect (Watts and Strogatz 1998) describes the characteristics of networks: if the number of nodes in the network increases, while connected by a short path, the total length of paths will increase logarithmically and a high level of clustering will occur;

4. The increase of connectivity of nodes in a network depends on the fitness to compete for links (Bianconi and Barabási 2001). This fitter-gets-richer phenomenon helps to understand the evolution of competitive systems in nature and society;
5. Robust networks are formed by numerously connected nodes, which are highly clustered and know a minimum distance between any random pair (Solé et al. 2002).

These characteristics have been applied to a concrete spatial situation in preliminary research (Hao and Wang 2010). In order to determine the points in the network with the greatest potential to start change, the networks were analysed in two steps: (1) the density of individual networks and (2) the number of different network types colliding at one physical location.

The first step examined the density of nodes, defined as: the number of nodes within a grid cell of 10 × 10 km, combined with their importance. In this case study the importance was weighted on a scale of five (minor element = 1; mediocre = 3; and major = 5). The results, in the form of maps for the energy, water and transport network, are shown in Fig. 4.10.

The second step analysed the number of different networks that form a node: one (only water, energy or roads), two (any combination of two) or three (all). When two types collided they were added to the calculation by a factor of 10 and in case of three network types by a factor of 100. Within each grid cell of 10 × 10 km, all nodes were calculated and added to a total score per cell.

Finally, the values of individual networks (1) and network types (2) were added to give the total score for each grid cell (Fig. 4.11). Higher scores imply a better starting point for change.

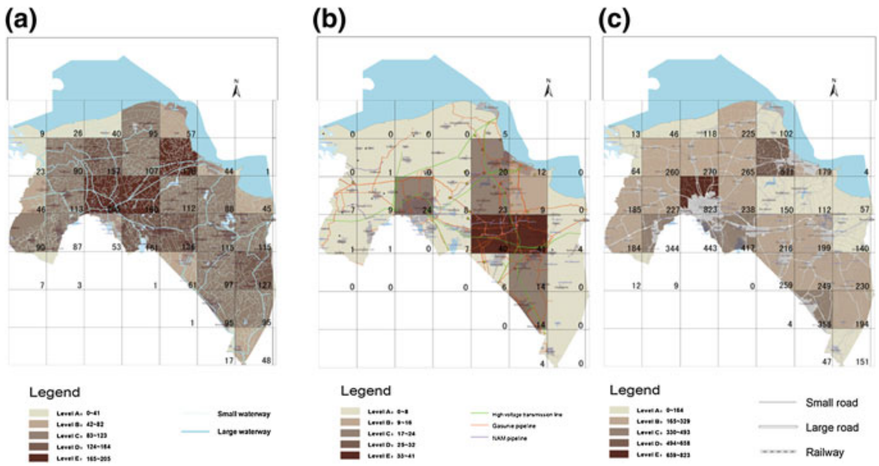


Fig. 4.10 The network maps of water (**a**); energy (**b**) and transport (**c**) (Hao and Wang 2010)

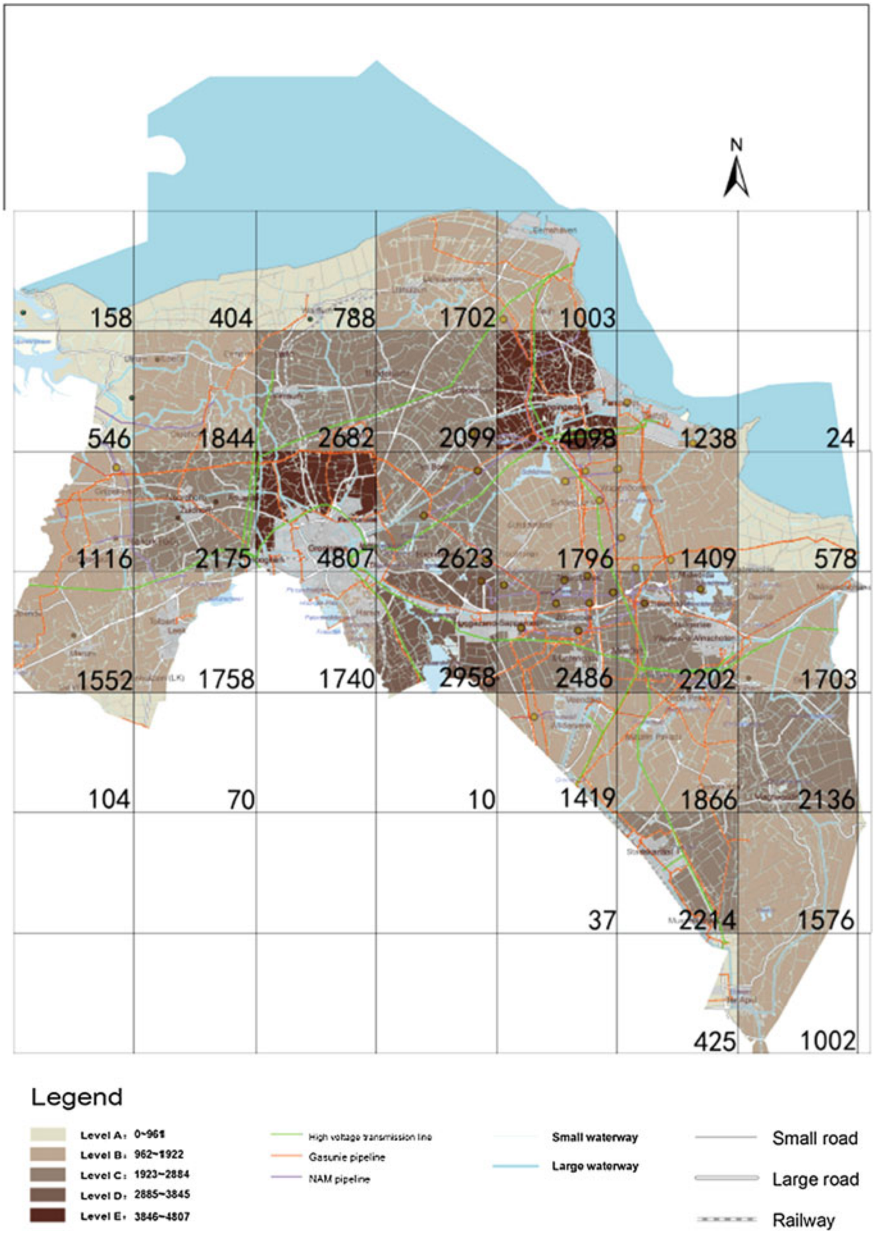


Fig. 4.11 Integrated density of networks for Groningen area (Hao and Wang 2010)

The integrated map illustrates that in this case certain grid cells are more likely to start a system change than others. In the next section identification of these starting points for system change are elaborated in a case study.

4.7 Application in the Peat Colonies

The developed theory of transformation of spatial patterns, as well as the identification of the starting points of change, the *B-minus*es, has been applied to the case study of the Peat Colonies, an area in the northern part of the Netherlands. The Peat Colonies is an area where in the old days peat was extracted. After this transformation of the peat landscape in a rationalised agricultural area, where orthogonal straight canals and roads dominate, production of potatoes and sugar beets took over. Nowadays the area is confronted with a declining population, marginalised productivity and degrading soil conditions. The application of the developed theory was undertaken in the following steps:

1. Mapping existing networks. Each of the networks, water, energy and transportation were mapped and analysed. The water network consists of a dense pattern of canals and smaller waterways and contains a couple larger canals and natural streams. The energy network is determined by the larger gas- and electricity-grids and their fine mazes, delivering energy to individual homes. The transportation network consists of the main roads and railways and the denser local streets.
2. Identifying 'announcing' nodes. The key nodes in the networks are identified by the density and connectivity of individual nodes. The ones with the densest and connective links are seen as the places where a potential system change might occur. Hence these nodes are identified as the ones that announce an upcoming change. When or how this change will happen is difficult to predict. These nodes are represented on the maps as small circles (Fig. 4.12). These nodes function as *announcer* '*B-minuses*'.
3. Determine 'creation' nodes. The analysis of the networks (e.g. the key nodes) in relation with existing urban (residential, industrial) functions and existing network infrastructure appoints us at areas that are positioned in developmental vicinity. These areas are represented in the maps as ovals (in the transport network) or rectangles in the energy network (Fig. 4.12). Here the nodes can be created that are capable to start transformational change, the *creating* '*B-minuses*'.
4. Climate proof design. The final stage of the application was the use of the identified nodes in the spatial proposal for a climate proof area (Fig. 4.13), in which mitigation and adaptation strategies are combined. The nodes were taken as the directing force for this design. After having identified the key nodes in the networks and the accompanying areas with high developmental potential, the choice for a specific development still needed to bemade. Fundamental for

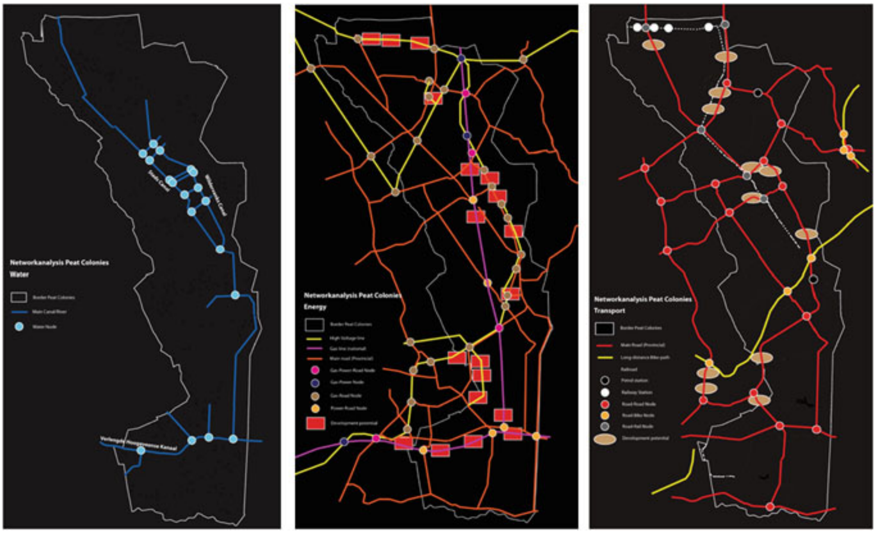


Fig. 4.12 Key nodes in the water- (**a**); energy- (**b**) and transport network (**c**)

this choice has been whether areas are seen as ordinary development areas, e.g. new urban neighbourhoods or economic development zones, or as areas that provide climate adaptation and mitigation contributions. In this case study the choice has been made for the latter option. Among others the following examples are proposed in the design:

- Self-sufficient villages are combined with decentralised large-scale energy generation in the South East. Here the innovative Algae greenhouses are projected as well. A heat-ring is projected to connect these greenhouses with geothermal production areas and transport the heat towards consumers in the larger towns.
- Two low-lying areas are created for floating algae greenhouses, in combination with storage of surpluses of rainwater. These areas function as the connecting zones of so called 'water-farms', where water-based agriculture is practiced and clean water is provided, between the eastern and western parts of the Peat Colonies.
- The best-connected nodes in the energy network are used to form the starting points of the heat networks. These isolated areas function in the beginning as solitary elements, but can be connected with each other using the energy network, at a later stage. One big robust heat network emerges.
- Other towns and villages are provided with heat from local supplied renewable energy sources, of which the location is based on the local available renewable energy potentials of heat-generation and storage in the soil.

These spatial elements will start broader developments and emergence of other related functions. The application of the theory in the Peat Colonies illustrates that

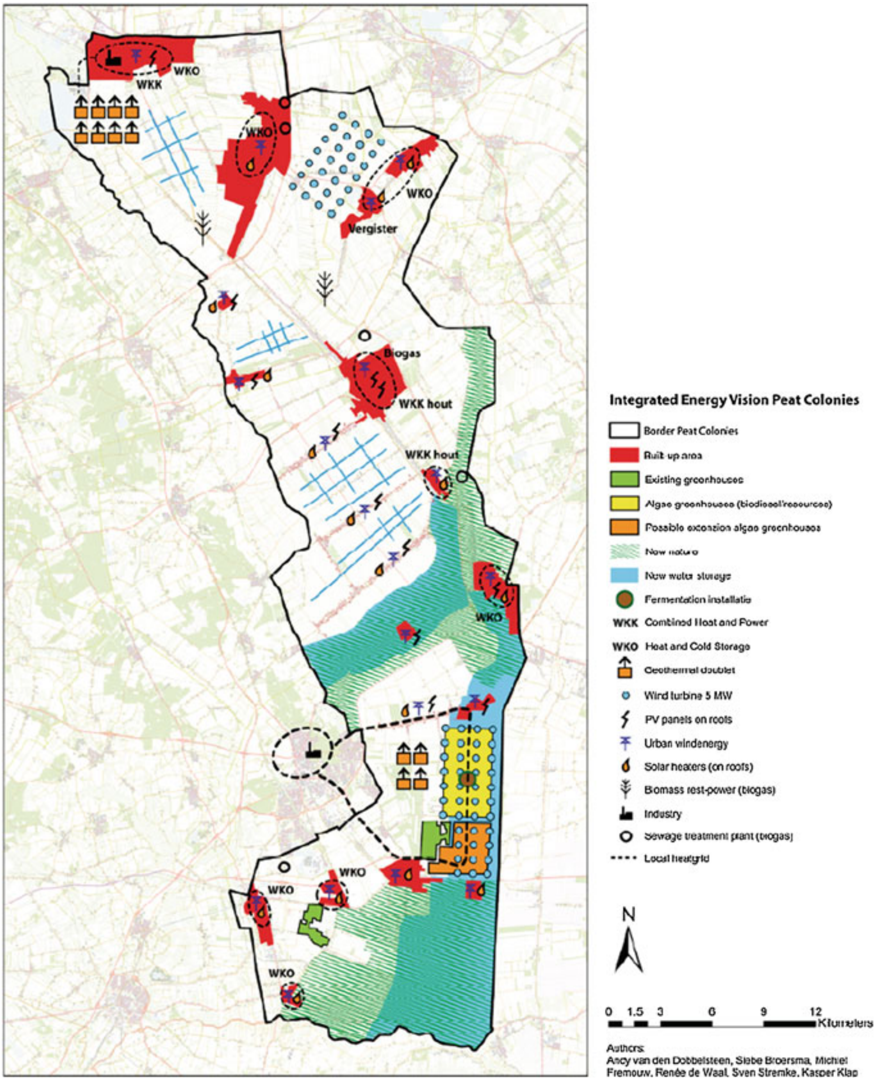


Fig. 4.13 Integrated climate adaptive design for the Peat Colonies (Boersma et al. 2011)

network analysis provides information about the strategic key nodes in an area, which subsequently can be created as the starting points of development. The fundamental choice to let these locations play a role in mitigating and adapting climate change can provide a transformation in the landscape, which operates as a climate proof landscape.

4.8 Conclusions

As presented in this chapter, current spatial planning has difficulties to incorporate the topic of climate change because it imposes change in the spatial system and the majority of spatial planning trajectories aim for an unchanged or only marginal changed spatial layout. This tension between the need to change the spatial layout as a result of climate change and the inherent characteristic of spatial planning to preserve the layout as it causes problems on the long term. In principle three pathways describing change can be distinguished: incremental change, transition and transformation. When change is expected to be fundamental and to confront society with the need to change substantial parts of its spatial layout, transformation offers the most suitable description of navigating those changes. In this chapter it has been concluded that transformation implies the change towards a fundamental new system, which fits with the need to change substantial parts. Therefore transformation is studied in more depth.

A transformation does not happen out of no-where, but it announces itself already while the existing system still operates (Ainsworth-Lands 1986). In this chapter we have taken this fact as the starting point and this resulted in the definition of *B-minus*, the elements that announce or enhance a system change. The search for these elements makes it possible to understand and explain, announce and ignite a transformation. The discovery of *B-minus*es helps to identify the announcement of a system change and the creation of *B-minus*es supports a system change.

Early warning systems can be discovered, announcing the approach of a threshold and system change (Scheffer et al. 2009). These early warning signals are found in several types of systems, with exception of spatial systems. The first attempt to define these signals in spatial dimensions has been demonstrated here, but this requires further elaboration.

The other way is to create *B-minus* elements, which, most likely then start a system change. Learning from network theory, the most intense nodes in networks and the most connected networks are the places where these elements can be estimated to emerge. More elaborate research is required to define these locations in the network more precisely.

The application of the developed theory in the case study of the Peat Colonies illustrates that transformational change can be enhanced on the basis of network analysis, identification of key nodes that announce a potential change and the creation of development locations where key nodes, existing infrastructure and urban functions are related to each other. The way these locations are developed determine whether the area as a whole is transforming towards a climate proof region, as has been illustrated here, or towards other forms of urban development. When the locations are specifically directed in mitigation—or adaptation futures, the entire landscape is most likely to transform in that direction.

Table 4.2 Characteristics of pathways leading to respectively A-apostrophe and *B-minus*

A-apostrophe	B-minus
Tame problems	Wicked problems
Moderate environments	Turbulent environments
Transition	Transformation
Linear thinking	Non-linear (dynamic) thinking

In conclusion, the pathways leading to *A-apostrophe* and B respectively (Table 4.2) have fundamental different properties. The A-apostrophe pathway is useful to enforce change if tame problems in relatively steady environments are to be dealt with. In this case linear thinking and a transition pathway can be used. However, if a wicked problem must be dealt with and the environment is complex, transformational change and non-linear thinking are more suitable to facilitate change.

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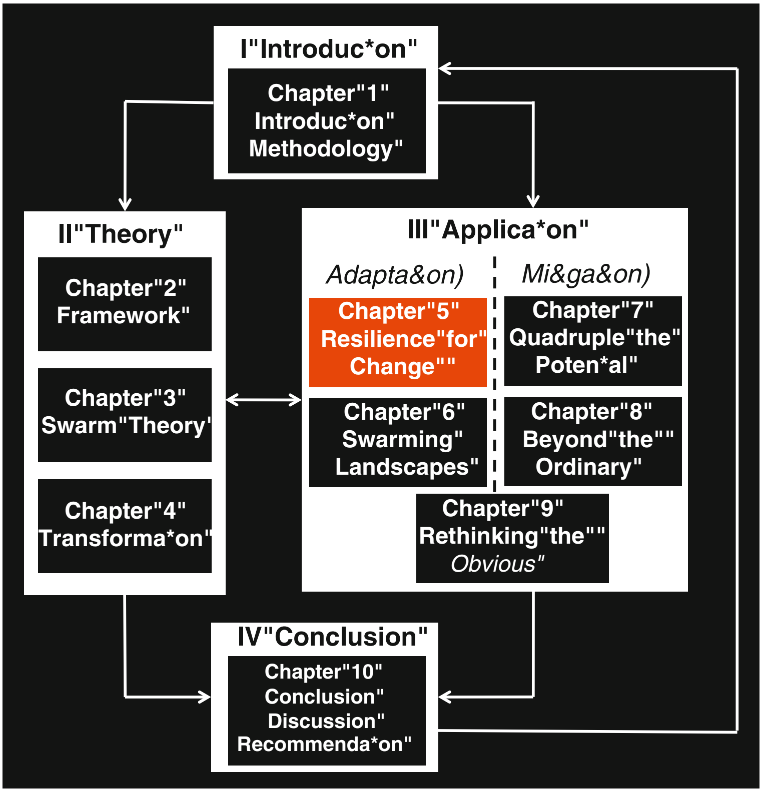
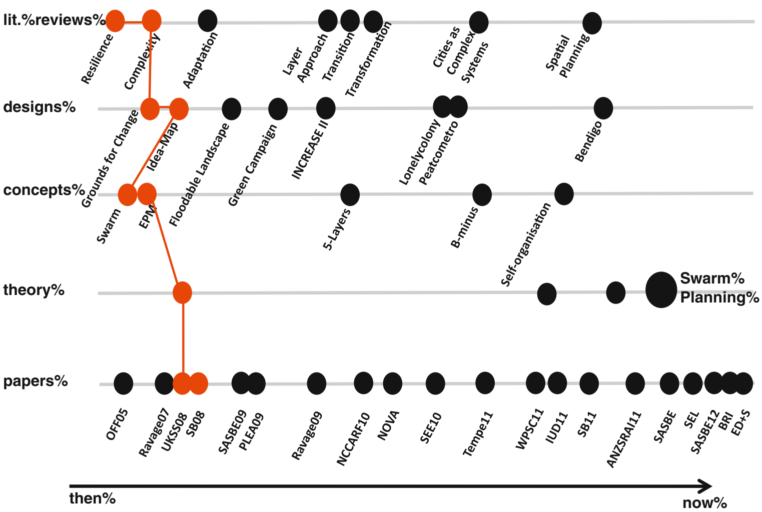
The Bridge: Four–Five



In Chaps. 2, 3 and 4 the theoretical basis is found for a spatial planning framework that is capable of dealing with complex issues, such as climate change. In Chaps. 5–9 this framework is applied to (practical) case studies. Chapters 5 and 6 focus on climate adaptation and the increase of resilience. In Chap. 5 the way a strategic intervention can be best placed in conjunction with creation of free space for spatial evolution is further elaborated for the case study of the Regional Plan for Groningen Province. The first statement in this chapter is that a spatial system functions as a complex adaptive system (CAS) and the chosen planning process to develop the regional plan does not acknowledge this. The planning process needs to be adjusted in order to give space to the wicked character of climate change: a 'wicked bypass' is introduced. Secondly, the complex spatial system can become more resilient when it reaches a higher level of complexity. A strategic intervention, or tipping point, might enforce the system to reach this new level. In a spatial sense a specific location needs to be identified where this strategic intervention can be placed. Extensive knowledge and understanding of the spatial system is necessary to confidently locate these places. Therefore, the climate and energy data are spatially mapped and the most suitable interventions are located in the spatial system. The care for a sustainable energy supply at the regional scale implies modifications in the landscape and in this sense energy supply is an adaptation measure. The resilience of the area is increased through implementing the strategic interventions and to create space around them. This chapter is published in the conference porceedings of UKSS 2008 and SB08.



Chapter 5
The Use of Spatial Planning to Increase the Resilience for Future Turbulence in the Spatial System of the Groningen Region to Deal with Climate Change

5.1 Introduction

The province of Groningen is responsible for a good spatial policy. Main focal areas of interest are living, economic and social development, water management, transport and traffic environmental policy. These fields are integrated on a regular basis in a regional plan, which is made for the entire provincial area. In 2008, a new regional plan has been developed. The circumstances and context determine the content of the plan in a strong way. The current timeframe distinguishes itself in the way long-term developments appear. The supply of energy is uncertain, because fossil resources will be depleted within 40 years from now. The changes in climate are unpredictable as well, but they will have, for sure, a major impact on society. The turbulence in today's and the future's world is and will be strongly determined by the issues of energy supply (and prices) and climate change (and disasters). For a province it is important to respond to these developments in the most appropriate way, i.e. with the lowest risk and the lowest chance on problems for its inhabitants. The province of Groningen wants to be prepared to withstand eventual rapid changes and prepare its people by increasing resilience in its spatial planning (Roggema 2008a). In order to create more resilience in its regional plan the province explores in several research steps (Fig. 5.1) the adaptability of spatial

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This chapter has previously been published in the double blind peer reviewed conference proceedings of the UK Systems Society conference Building Resilience: Responses to a Turbulent World, Oxford, 1–3 September 2008: 'Roggema, R. (2008) The use of spatial planning to increase the resilience for future turbulence in the spatial system of the Groningen region to deal with climate change'. A more concise version has been published in the double blind peer reviewed conference proceedings of the World Sustainable Building Conference, Melbourne, 21–25 September 2008: 'Roggema, R. and A. van den Dobbelsteen (2008) Swarm planning: development of a new planning paradigm, which improves the capacity of regional spatial systems to adapt to climate change' and received the scientific award for the best paper during this SB08-conference.

R. Roggema, *Swarm Planning*, Springer Theses, DOI: 10.1007/978-94-007-7152-9_5,

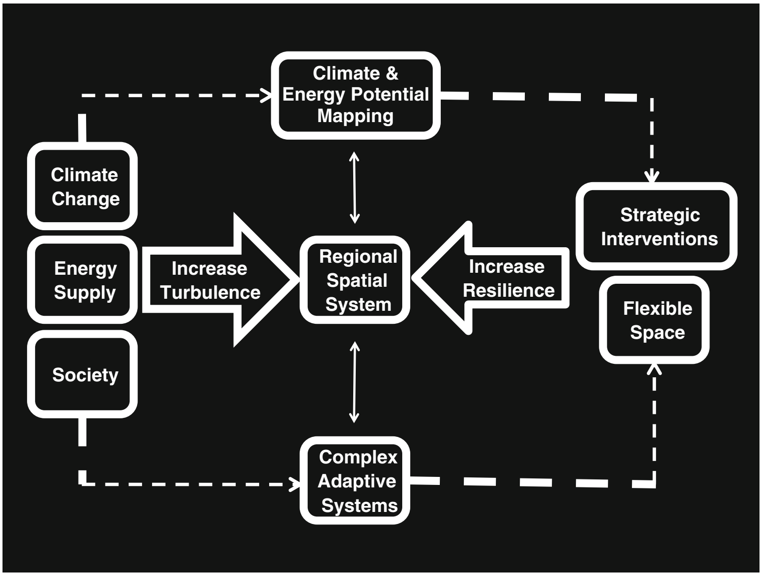


Fig. 5.1 Research elements: Interrelatedness and mutual influences

systems and the way they may be influenced. In Sect. 5.2, the background of climate change on a sub-regional level as well as the relevant aspects of complexity and adaptive systems are explored. This section concludes with the characteristics of an emerging new planning paradigm: swarm planning. Section 5.3 explores the possibilities to use this planning paradigm in the Groningen case. This contribution finishes with a discussion on the benefits and disadvantages of the new paradigm (Sect. 5.4) and finalises with conclusions (Sect. 5.5).

5.2 Background

As a background for the project two fields are important. First of all, the regional impact of global warming, leading to changes in climate at a regional level, gives insight in the amplitude of turbulence, originated by climate change. Secondly, the way in which adaptation can be included in planning requires insights in the adjustability of a planning paradigm when confronted with a turbulent environment. It is assumed that complexity theory and knowledge on adaptive systems may support the planning system in dealing with turbulent matter: the challenges of complexity in planning.

5.2.1 Climate Change

Global warming develops slowly, but continuously. In the recent 150 years temperatures on earth have clearly increased. It takes a long time to stop this process, decades or more. The warming process reacts very slowly, because warming of the atmosphere indicates a slow warming of oceans and they are, with their large warming-capacity, not able to react fast. The emissions of greenhouse gases of recent decennia, combined with current emissions, lead to a continued global warming for at least the next decades (IPCC 2007a, b). Therefore, global warming needs to be reduced by decreasing emissions, but it is inevitable for mankind to adapt to climate change as well. In the Groningen project the adaptability within the regional spatial plan is one of the main issues (Van den Dobbelsteen 2006).

Dutch climate scenarios

The Dutch Meteorological Institute developed four climate scenarios for the Netherlands (KNMI 2006). The scenarios for 2050 are based on two variables, which influence the Dutch weather in particular: changing air patterns and temperature rise. Thus, four scenarios are defined (Fig. 5.2): G (no change in air patterns and 1 °C rise of temperature), G+ (changed air patterns and 1 °C rise), W (no change in air patterns and 2 °C rise) and W+ (changed air patterns and 2 °C temperature rise). The changed air patterns imply a more moderate and wet winter caused by a dominant western wind as well as increased dry and warm summers, caused by a dominant eastern wind.

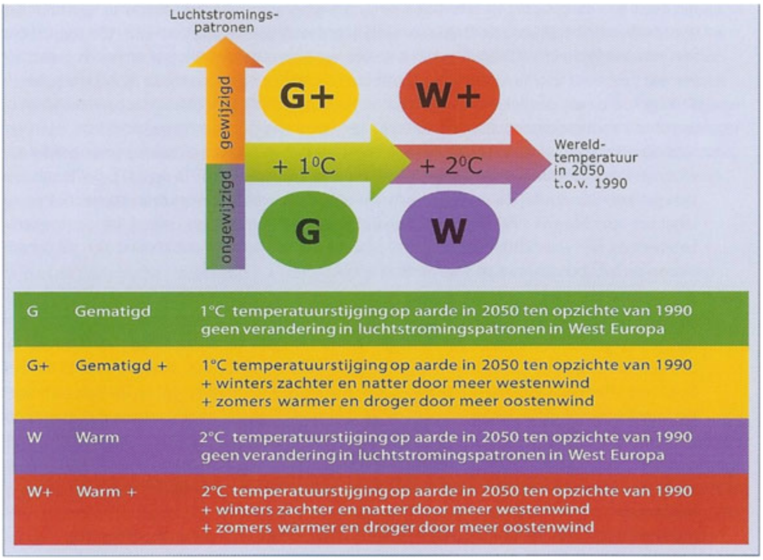


Fig. 5.2 Climate scenarios for the Netherlands (KNMI 2006)

Table 5.1 Two scenarios (2050) for Groningen (Roggema 2007a)

	Royal Dutch Meteorological Institute (KNMI)-scenario	Accelerated Melting Land Ice-scenario
Precipitation spring and autumn (%)	+20	+30
Precipitation summer (%)	−20	−40
Precipitation winter (%)	+15	+30
Temperature	+1.5	+3.0
Sea level rise (cm)	+35	+150

Climate scenarios for Groningen

The province of Groningen (Roggema 2007a; DHV 2007) developed two scenarios, which are based on one hand on the KNMI-scenarios and on the other hand on a scenario, which reflects the changes if an accelerated sea-level-rise takes place. The four KNMI-scenarios were combined into one scenario, which corresponds to the higher expectations of the KNMI (W+ scenario). An accelerated melting of the land ice masses of Greenland and Antarctica forms the base of the second scenario (ACIA 2005; National Geographic 2007). Both scenarios are defined for 2050. In Table 5.1 parameters of these scenarios are summarised. Both scenarios were developed to show the broad range of possible futures. Development of robust policies for Groningen is based on the full bandwidth of the two scenarios. In this way, even very unlikely developments and events are included in policies, which make society better prepared for the future and more resilient.

In the course of history, climate has always changed. The discussion is about whether this change is caused by human activities and how the pace of changes will develop in the future. It is expected that the objective of stabilising the rise of temperature on a level of +2 °C by the end of this century, compared to the level of 1990, will be difficult to achieve. A rise with 3 °C or even more is more likely to happen. The sea level might have risen by then with at least 1 m and—if ice-sheets of Greenland and the Western Antarctic are melting more rapidly—even more. Furthermore, it is impossible to minimise or reduce the emissions of greenhouse gases to zero immediately. Even if this would be possible, temperature on earth and the sea level would continue to rise for the next decades.

This results in multiple urgencies: First of all, energy must be produced in a way that minimises the effect on global warming, by making use of local capacities to produce energy and eventually to switch to a hydrogen economy (Rifkin 2004). Secondly, man has to adapt to the effects of climate change. And finally, the economic impact will be huge (Stern 2006).

5.2.2 Challenges of Complexity in Planning

Current planning methods are being challenged by several developments in society. Society itself is changing from an industrial society towards an Internet society (Toffler and Toffler 2006). Beside the changes in society, the same society is confronted with more and more turbulent circumstances. Uncertainty about the future is increased by long-term changes that are ahead of us. Climate change and energy supply are two important examples of this. The current planning system creates an end-image of the future in which current problems are solved. But this way of planning no longer satisfies, because the problems we face today are complex and long-term oriented. The question is if current planning systems contribute to the building of resilience into society or that another planning system is needed to do so. Planning has the assignment to react to the uncertain developments of the future and has to contribute to the generation of resilient communities. The theory on complex adaptive systems may help planning to adjust itself to the new questions and to give answers to these new challenges. A new planning paradigm might emerge. This chapter elaborates on the theoretical background of increasing complexity in planning.

A society in turbulent circumstances

Today's society is confronted with an increasing turbulent environment. Emery and Trist (Emery and Trist 1965) describe turbulent environments as follows: *"the dynamic properties arise not simply from the interaction of the component organisations, but also from the ground itself. The 'ground' is in motion".* Translated to the spatial planning field, the spatial elements or components (buildings, infrastructure and people) do not only interact and form a system together, but dynamic properties also arise from the ground itself. Literally: from the soil, the natural system itself. This natural system is currently influenced, and will be in the future, by a mass depletion of fossil energy resources, a relatively rapid climate change and a transformation to an Internet economy. These 'external' factors and 'inclusive' properties of the natural system itself, cause a turbulent environment for the spatial system. The energy supply system, climate change and the Internet-economy have similar characteristics. They:

- Are complex and difficult to overview and understand at once;
- Include lots of uncertainties;
- Are strongly interrelated with other functions and with each other;
- Have impact on the long-term.

The fact that these phenomena are difficult to understand also implies a new environment for spatial planning practice. The unpredictability of interrelated long-term developments leads to a decreasing grip of the planning system on future developments, because traditional planning methods (blueprints, short-time oriented) are no longer useful (Roggema 2008c).

Thus, the new demands are difficult to integrate in spatial planning practice (Fig. 2.1). The planning system is too stiff and not easy adjustable. To increase the flexibility of the spatial system theory on complex adaptive systems may be used. The objective is that the resilience of the spatial system increases in order to deal with unexpected and unpredictable developments. The resilience of the spatial can be defined using the ecological definition of resilience: *"The capacity of a system* *to absorb disturbance and reorganise while undergoing change so as to still retain essentially the same function structure, identity and feedbacks"* (Walker et al. 2004). The Groningen case (Chap. 3) shows a method and the first results how resilience can be improved.

In this paragraph, a short description of the changes in society is presented. The way these changes malfunction in the current planning system and the way today's planning community deals with this increasing gap will be explored. Furthermore, the theoretical background on complex adaptive systems is researched and used to design a new planning paradigm, which is better prepared to deal with turbulent circumstances.

Internet-economy: the turbulence driver

In the Internet-economy, people are no longer only consumers of news, adds or products, but they become also a generator of information and are able to deliver to the Internet in order to share their deliveries with others (Bakas 2005, 2006; NRC Next 2007; Eye Magazine 2007). This free space of exchange, where every consumer is also a producer, could influence the spatial design of regions. Society is transforming from an industrial economy, based on power and position, towards an Internet economy, based on values and knowledge (Toffler and Toffler 2006; Greenfield 2003). The impact individual people or collectives of individuals generate to (trans) form society, just starts to become visible, but will increase in the near future (Roggema 2008b), when a landscape 2.0 could emerge. The following transformations can be seen already:

- It is no longer useful to create an end-image of a society, constructed by politicians and used to determine how people behave. People need to be seduced to change or show certain behaviour. Society emerges as a result of the interactions and summed up behaviour;
- Climate change is an illustration of how an increasing series of complex interactions lead to problems, which occur and become apparent at a later stage. The exact relations between interactions and effects are impossible to overview by individuals;
- The new economy is a connection of people, ideas and information. In this new economy flexible network organisations take over. In this new world, it is more important to be a connector of knowledge than an owner of goods. Possession is not the key factor. The key factors are the immaterial additions to the network and the exchange of information;
- When the transition to an Internet-economy is used to understand future changes caused by climate change and energy supply, new landscapes lie in front of us. It is no longer only possible to consume landscape for living, enjoying or production it can also deliver climate resilience and supply energy to the spatial environment.
- People add individual elements to a bigger world, knowing—partly unconsciously—that they are part of a system, built out of billions of parts and consisting of unpredictable interactions. They realise that it is impossible to single-handedly create one future state of society. They know that individual

contributions and interactions form the future. While it seems that people are only concerned about their short-term happiness, look at the way they vote for instance, yet their inside voice tells them that they are constantly shaping the future in a way that is difficult to understand.

These changes in society offer a chance to adapt more easily to climate change, because large groups of people intend to work together, not in a power based way, but based on the contribution of values. This state of mind opens views to a stronger built society than the hierarchical one, because people are no longer just consuming energy or political messages, but they start to produce them their selves and start to contribute. Instead of a one-way society a 'both ends' society is emerging.

The state of today's spatial planning practice

Climate change is a long-term development. Starting today, the changes will continue for the next century and beyond. Building houses and generating urban patterns are processes with a similar time span: they also last 100 years or more. Thus, in theory, it should be easy to combine and integrate long-term changes and developments with spatial planning. In practice however, spatial planning mostly fixes its horizon on a period of maximal 10 years (Fig. 5.3). This short-term focus in a situation, where long-term changes are predicted creates unnecessary difficulties. Although it is relatively easy to incorporate long-term changes into the spatial planning system, the issues of climate change and energy supply are only rarely found in current spatial plans.

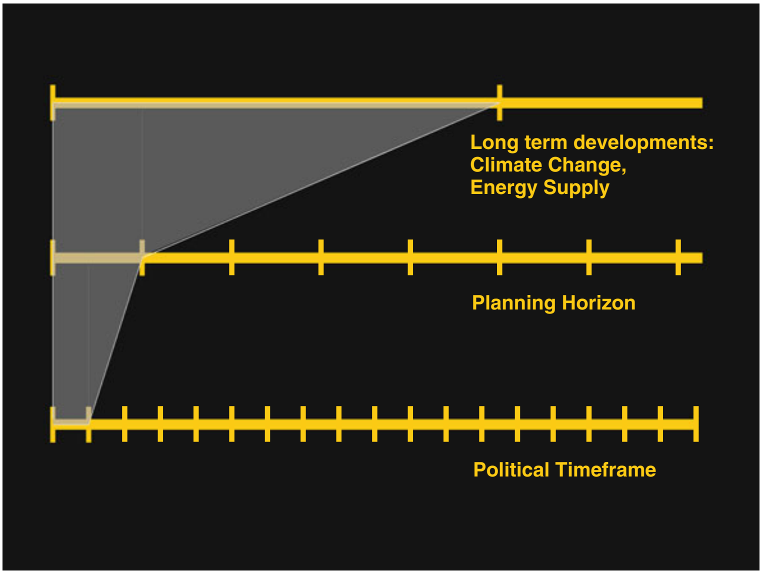


Fig. 5.3 Connection of long- and short-term (Roggema 2007b)

The spatial planning system that is used today is not very flexible. Current problems are analysed and formulated in quantitative terms as much as possible: number of houses, acres of land for new industrial areas, needed area for ecological structures etcetera. Once the decision is made, the size of developments and the objectives are fixed. This may be called a tame planning method, in which rationality and a normative approach is dominant. Conklin (Conklin 2001) characterises tame problems as follows:

- Relatively well-defined and stable problem statement;
- Definite stopping point, i.e. we know when the solution is reached;
- Solution can be objectively evaluated as being right or wrong;
- A problem belongs to a class of problems which can be solved in a similar way;
- Solutions, which can be tried and abandoned.

Because the focus is on the first couple of years, it is difficult to include long-term and complex elements into the planning process. This causes a laborious adjustment of turbulence matter in the tame planning methods. To incorporate the turbulent environment into a spatial planning method an adjusted method (Fig. 5.4) must be developed, in which room is created for a wicked (as the opposite of tame) bypass (Roggema 2008d). If this bypass is included in the process, these turbulent environments are given the surroundings in which they fit: irrational, unsolvable problems are placed into a wicked process.

Rittel and Webber characterise wicked problems by ten characteristics (Rittel and Webber 1973):

1. There is no definite formulation of a wicked problem;
2. Wicked problems have no stopping rules;
3. Solutions to wicked problems are not true or false, but better or worse;
4. There is no immediate and ultimate test of a solution to a wicked problem;
5. Every solution to a wicked problem is a “one-shot operation”; because there is no opportunity to learn by trial-and-error, every attempt counts significantly;
6. Wicked problems do not have an enumerable (or an exhaustively describable) set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated in the plan;
7. Every wicked problem is essentially unique;
8. Every wicked problem can be considered to be a symptom of another {wicked} problem;
9. The causes of a wicked problem can be explained in numerous ways. The choice of explanation determines the nature of the problem’s resolution;
10. [With wicked problems,] the planner has no right to be wrong.

New environment for planning: small adjustments made

Recently, the first small adjustments in the current planning system become visible. The planning community becomes more aware that their environment is changing towards an increased turbulence. Therefore, an increasing number of

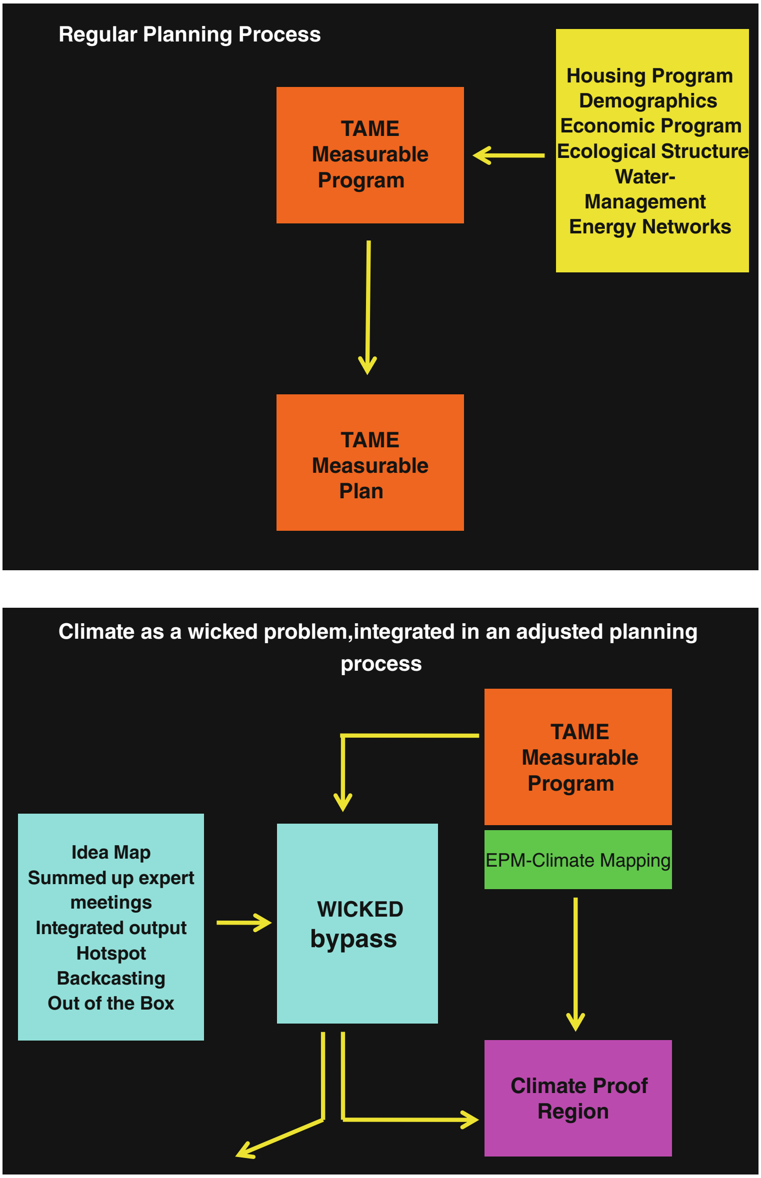


Fig. 5.4 Comparison of a tame planning process and a wicked one, in which is more room for turbulent adjustments (Roggema 2008d)

projects are carried out in a more interactive way. In the planning processes, more stakeholder involvement is organised and the co-operation is improved. In the Netherlands, this kind of planning processes are called development planning or area development. The following characteristics of this planning approach are defined (Zonneveld 1991; Schön and Rein 1994; Castells 1995; Teisman 1997; Dammers 2000; Innovatienetwerk 2002; Esselbrugge 2003; Rooy et al. 2006; Van Dijk 2006; Ruimtelijk Planbureau 2004; Adviescommissie Gebiedsontwikkeling 2005; IPO 2001; VROM 2003; VROM-raad 2004, 2006; WRR 1998):

- *Include a specific defined intervention.*
  In planning processes a well-defined impulse, which is capable of starting the engine of the system is included. This intervention needs to be very specific and located, with a strong emphasis on the impact it has or is expected on changes in the system (the system innovation).
- *Choose some kind of fuzzy future direction*
  A dynamic planning process takes the future dynamics of society as starting point and needs to offer room for unpredictability by initiating a certain direction, which fits best in the broad band of future dynamics.
- *Enhance a higher level of complexity in the region*
  To increase the overall fitness in a region the system has to be brought to a higher level of complexity (Homan 2005). It is expected that this implies a higher level of resilience. The overall fitness of a system increases by bringing together a large pool of elements (a lot of participants), which co-evolve and are able to reach a creative jump (Homan 2005).
- *Create a permanent dynamic process in which participants often change*
  Participants involved in the process tend to defend original concepts and to act defensively towards possible changes in these concepts. To prevent this from happening, an atelier might be introduced, in which one group of involved partners defines and executes an intervention after which the lead is given to the next group, which makes its own creative jump.
- *Keep numerous perceptions involved in the entire process*
  The amount of perspectives in innovative processes is large. Instead of aiming to converge the perceptions in the final phase of the process it might be better to keep several perceptions, which exist next to each other in different constellations and enrich each other like in internet communities.
- *Prevent cultural patterns from inducing repetitive solutions automatically*
  Cultural patterns in organisations lead to repetitive solutions, produced by those organisations, even if the problems and issues are new. If a discussion is started on the applicability of these solutions, these organisations tend to close the ranks and strengthen their believe in the existing solutions (Roggema 2005). It is estimated that this effect increases if councillors take responsibilities for longer periods (three terms or more).
- *Use projects to start processes, not to finish them*
  Projects function as a spatial-functional impulse, which are able to change future pathways in long-term problems like climate change and energy supply. Thus, these projects are not aiming to create an end image for the future, but to start the building of a system of higher complexity, which is supposed to be more resilient.

The question remains if the adjustments the planning and design community carries out in the planning processes are strong enough to deal with real turbulent circumstances. Probably, it does not meet these demands, because the adjustments are done within the existing (tame) planning system. Larger adjustments are necessary. Therefore, the main objective for a new planning paradigm is to increase the capability to build up resilience for turbulent circumstances.

Increase resilience

Resilience is defined as: “the capacity of a system to absorb disturbance and reorganise while undergoing change so as to still retain essentially the same function, structure, identity and feedbacks” (Walker et al. 2004; Walker and Salt 2006). Thus, the increase of the resilience of a system means that a system is better capable in absorbing disturbance. When a system is placed into a turbulent environment it is necessary to increase adaptability in order to deal with turbulent ‘attacks’ on the system. Adaptability is defined as the capacity of actors to influence resilience.

The crucial aspects of resilience are the following (Walker et al. 2004; Walker and Salt 2006):

- Latitude: maximum amount a system can be changed before losing its ability to recover (before crossing a threshold);
- Resistance: ease or difficulty of changing the system;
- Precariousness: how close the current state of the system is to a limit or ‘threshold’;
- Panarchy: the resilience of a system at a particular focal scale depends on the influences from states and dynamics at scales above and below (for instance global climate change).

Actors in the system are capable of managing the resilience of a system and influencing the adaptability of the system. The collective capacity to manage resilience determines whether the actors can successfully avoid crossing into an undesirable system regime or return to a desirable one. Actors may use four ways to influence resilience and increase adaptability:

- Move thresholds
- Make the threshold more difficult to reach
- Move the system away from the threshold
- Avoid loss of resilience by managing cross-scale interactions

If the adaptability can be increased the system has better chances to deal with turbulent circumstances, because it is easier for the system to absorb disturbance and reorganise itself while undergoing change. The level of complexity of a system may very well be a crucial factor in determining this system’s capability to adapt. Is a simple system less adaptive and is it less capable of influencing resilience? And do complex systems contain a higher capacity to do so, which make them more adaptive? If so, this offers spatial planning an opportunity to deal with turbulent circumstances: The regional spatial system is a complex system, which functions according the rules of complexity, adaptability and resilience. Thus, the planning system should be organised according to these rules as well: the first images of a new planning paradigm.

Complex adaptive systems

In order to deal with turbulent circumstances, the adaptability of systems can be increased if the collective capacity to manage resilience is improved (Walker et al. 2004). This requires a collective view on the future 'dream', the collective future objective. This collective view can be better developed if the characteristics of self-organisation are taken into account. Self-organising systems are capable of increasing adaptability, or increase their overall fitness (Homan 2005), and reach their complexity level by organising themselves. When a new 'view on the world' (i.e. a climate proof region) is shared by thousands of individuals, who start to aim for the same objectives, the system will auto-develop from that point on. Johnson (2001) describes the following guidelines:

1. Put more agents/cells (individual elements: streets, people, buildings) into the system and give them a longer trail, i.e. more impact;
2. Follow those trails, which make agents more sophisticated. The trail needs to be enlarged and interconnected to create a higher level order;
3. A huge pool of individuals and some simple rules;
4. Create the un-average. Social un-average elements are important as the announcers of what is happening in the system. The law of the few states that there is always a small number of un-average exceptions with extraordinary creativity, which may flourish between a 'bunch of average'. These exceptions play a crucial role in bringing the system to a higher level of complexity. If they are able to give a push or an impulse the system starts to evolve;
5. Unexpected solutions cause the adaptation of the system, which makes it more resilient and better prepared to adapt;
6. The regional city landscape is the complex adaptive system (Jacobs 1961). Find the kind and number of nodes (for example shopping mall areas), the transport system (freeway/internet), interactions and information-flows of our time. What are the new 'neighbours, sidewalks, communities, strangers and cities' (Jacobs 1961)?
7. Formulate the positive and negative feed back loops in order to reach a resilient regional community.

To improve collective management of resilience a collective new view on the world needs to be created and stimulated. Usage of advertisement and the creation of love marks (Roberts 2006) may be useful here.

The improvement of the adaptability of a self-organising system can be sustained best in complex systems, because the actors in these systems have, if compared to simple—closed/linear—systems, better capacity to do so (Fig. 5.5).

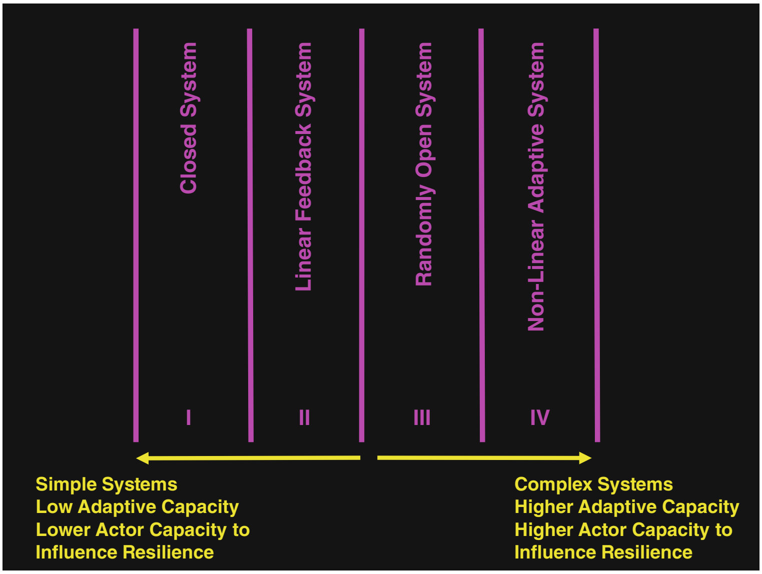


Fig. 5.5 Simple and complex systems

Typology of complex systems

Systems in general can be subdivided into four categories (Wolfram 2002): (I) closed system, (II) linear feed back systems, (III) systems randomly open to assimilation and (IV) non-linear adaptive systems. De Roo (2006) describes the characteristics of class IV systems. These systems are able to behave such as to maximise benefits of stability while retaining a capacity to change (Mitchell Waldrop 1992).

The question is how to interpret design projects in terms of complex systems. The following aspects of design projects are relevant:

- They contain a large number of interactions;
- Simple rules underpin complexity;
- Adaptation, self-organisation and co-evolution are apparent;
- The design transforms and retains the project;
- Design principles are characterized by robustness, emergence and fitness for purpose.

De Roo describes the same characteristics for class IV systems (De Roo 2006). In addition, experience shows that the subject of design is often sensitive to impulses and tipping points.

The question at this stage is which planning approaches would be most effective if the future consists of Class IV systems, manifest in a large number of interactions. The insights of organisation dynamics can be useful here. The conditions to improve the overall fitness of an organisation are (Homan 2005):

- Large groups of individual elements lead to emergence of collective patterns under certain conditions (amount of connections, quality of relations and network matter);
- Enough diversity but not too much to start autocatalytic processes;
- Idea-interaction (Homan calls it idea-sex) between different elements may lead to creative jumps where new structures and information is created;
- Co-evolution of local systems leads to emergence of collective patterns, enhancing the overall fitness of the system;
- Complex systems manifest several co-existing patterns (patches), rather than either one overall pattern or a large variety of local systems;
- Local ideas function as nuclei, eventually influencing and patronising large parts of a complex system.

The common characteristic in the conditions described, are large numbers and many interactions. There needs to be a large pool of elements. The chance that things interact increases and new processes cause the increase of the overall fitness of the system.

If systems of higher complexity are better equipped to increase adaptability and deal with turbulent circumstances, regional spatial systems should be brought to a higher level of complexity to be better prepared for turbulent circumstances as initiated by future climate change and energy supply. If the system is not randomly self-organising itself it requires some kind of incentive. New crucial interventions need to initiate a creative jump (Geldof 2002), which starts a process of increasing adaptability, leading to the change of the entire regional spatial system and to a more resilient system. What is missing so far is a trigger setting these processes in motion, such as a focal point that enforces the pool of elements to interact and starting the process of changing the system. These points, where 'dovecotes flutter', ultimately make things happen. Every element in the system orientates itself to these points, and by doing so the system as a whole changes. The result is an innovation coming out of a bunch of ideas. An impulse needs to be added in order to reach a tipping point.

Tipping points

The tipping point is that magic moment when an idea, trend or social behaviour crosses a threshold, tips, and spreads like wildfire. The possibility of sudden change is at the centre of the idea of the tipping point. Big changes occur as a result of small events. The situation is similar to the phenomenon of an epidemic. Epidemics follow three rules (Gladwell 2000):

1. The law of the few, a small part of the whole is doing all the work (80/20);
2. The stickiness factor: the message makes an impact. It is impossible to forget;
3. The power of context: sensitivity to the environment, influence of the surrounding.

By applying these rules to planning and design, the question when a design becomes a success, reinforcing the required changes, can be understood. First of all the law of the few tells us that a successful design will originate from a small group of individuals. The design is not what the common people expect. To change things the design will be away-from-the average (Ridderstråle and Nordström 2004; Florida 2005; Roggema 2005).

Secondly, the stickiness factor suggests that a successful design sticks in ones heads. Once having seen the image of the design it is not forgotten. Roberts calls it a visible love mark (Roberts 2006). A good example of this is the design for Almere Poort, the Wall (Fig. 5.6) (MVRDV et al. 2001).

Finally, the power of context in relation to design processes tells us that a design with huge impact provides the solution to a commonly felt problem. If a fundamental change is required, such as climate change is asking for, a widely shared context of deep trouble improves the chances of change. A sense of real urgency is required for fundamental change. A crisis will provide the energy to jump to the new situation (Timmermans 2004). If the existing system dissatisfies, a crisis is required to jump to the next level of complexity required to upgrade the system (Fig. 5.7) (Geldof 2002). These crises can be seen as the tipping points in design processes.

Geldof describes the relation between complexity, the level of order, the adaptability and the cyclic process of stabilisation and crisis (Geldof 2002).

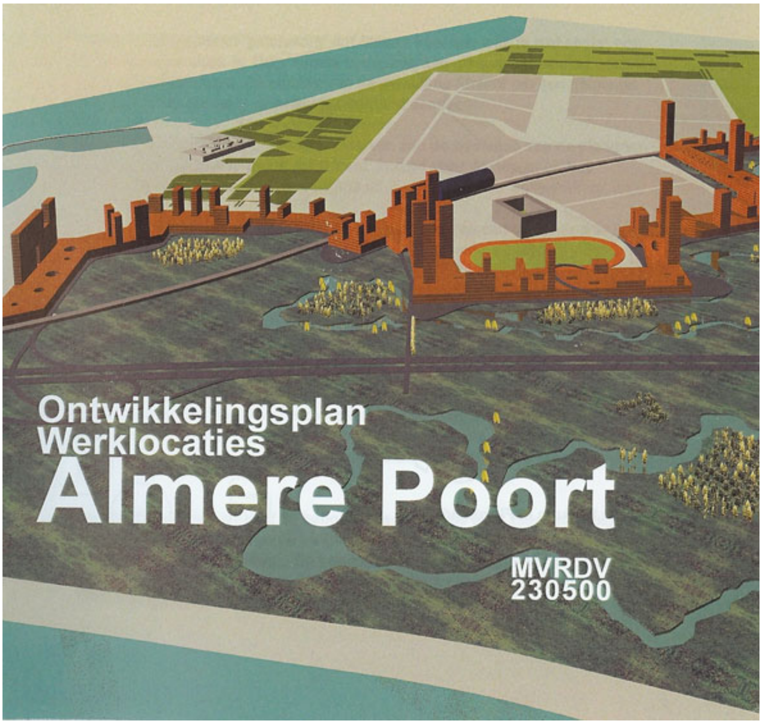


Fig. 5.6 The Wall in Almere Poort (MVRDV 1999)

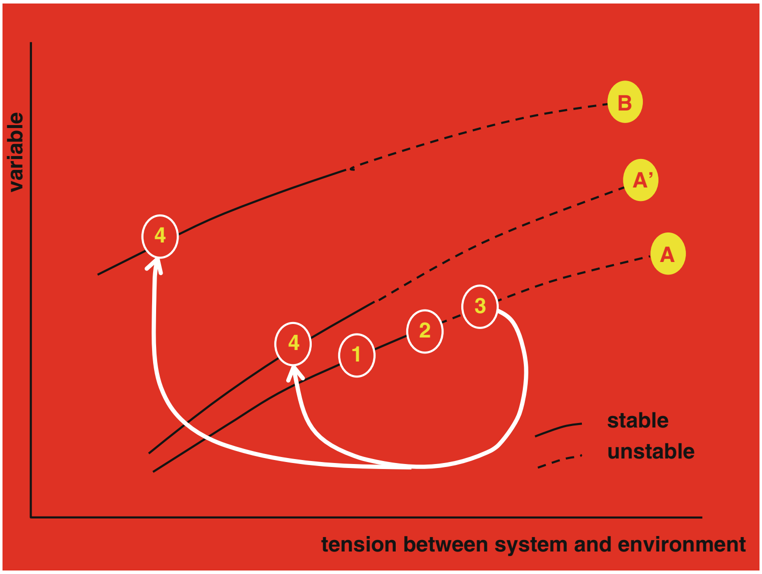


Fig. 5.7 Crisis enforces the jump to a higher level of complexity (Geldof 2002)

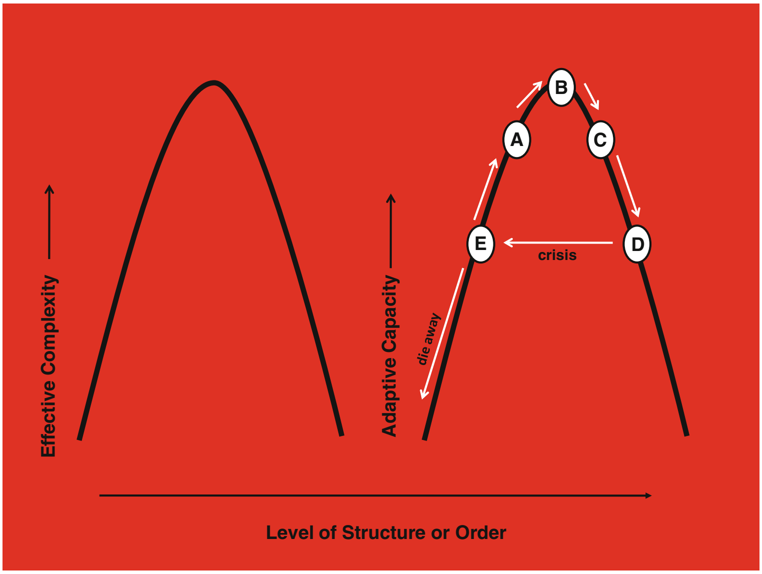


Fig. 5.8 Relation between level of complexity, adaptability and crisis (Geldof 2002)

If there is no order at all or a complete fixed order the complexity is low, but at the optimum point the highest complexity is reached (Fig. 5.8). At the same time, this point represents the highest adaptability of the system. A crisis is developing when the order of a system increases and at the same time the adaptability decreases. During a crisis, the system 'flips' from chaos towards the old trail. Two routes can be followed from that point on, depending on the availability of collective actors managing the resilience of the system and realising a creative jump (Fig. 5.7) (Geldof 2002; Homan 2005). The system dies or starts all over again. If a creative jump is made, the system is capable of evolving towards higher complexity and reaches a new stable situation with high adaptability (Fig. 5.8).

A new design paradigm, **swarm planning** (Jacobs and Roggema 2005)

Translated to planning design terms, the effective spatial intervention creates a tipping point, directing all spatial, societal, political elements in such a way that the entire region changes. Contemporary planning approaches only show little adjustments, while big ones are required to deal with the turbulence of climate change and energy supply. A new spatial design paradigm, following the rules of increasing adaptability in order to make areas more resilient, will emerge in reaction to new demands and developments. The first signs are there, but a structured approach is presented here. In this paradigm, which can be called swarm planning, (Roggema 2005), the role of spatial design is to introduce essential impulses to influence the entire system, like a swarm of birds is reshaping itself constantly under external influences, without changing its function. Spatial design will no longer be concerned with the entire image, but will focus on those essential design interventions that enforce the region to reshape. No blueprint design, but acupuncture planning.

Thus, for a swarm planning approach (Roggema and van den Dobbelsteen 2006) to be successful, two aspects are essential: the (spatial) characteristics of the region and the availability of extraordinary ideas. Complex systems theory suggests that the swarm paradigm will work where the following conditions are met:

- A large group of individual elements (people, buildings);
- Many connections (virtual, roads, rail, water);
- High quality of relations (fast, intense);
- High quality network (flexibility, intensity);
- Enough, but not too much, diversity (neighbourhoods, groups);
- Several co-existing patterns (patches).

If these circumstances pertain idea-mergers between different elements will lead to creative jumps, and new structures and information are created. A small group of extravagant idea creating people will enforce this and transform it into a sticky idea, which influences and shapes large parts of the region. If the sense of urgency is there—climate change for instance—a suitable trigger brings the idea to a tipping point and collective patterns emerge out of co-evolution of local systems, leading to an increased overall fitness of the system, which is able to adapt more easily to climate change, resulting in a resilient area.

This paradigm is not yet common, but the first examples in spatial design are there. The way interventions are planned in the design in the "Blauwe Stad", in the remote parts of Groningen province (Karelse van der Meer 2003), the projection of new islands in front of the Northern coast of the Netherlands (Roggema et al. 2006; Alders 2006; Boskalis 2006), but also in projects like the Öresund-bridge and its impact on the accessibility, economic welfare and image of Malmö and Copenhagen or the way Mendini (Mendini 1994) changed the entire inner city in Groningen through the Groninger Museum project are examples of swarm planning.

Swarm 'avant-la–lettre': The Groninger Museum

The "Verbindingskanaal" is a waterway at the edge of the city-centre of Groningen, located between the central station and the inner city. In the past, the easiest way to reach the inner city was to walk around the canal. As a consequence the area at the city side of the Verbindingskanaal became neglected, attracting hooligans and criminals. A representative of the municipality decided on the implementation of a new building in the canal, connecting the station with the inner city. As a result, the neglected part of the city centre changed into a very lively, attractive area, used by a large number of people. The intervention of building the Groningen Museum exactly at this location transformed the entire city (Figs. 5.9, 5.10).

5.3 The Groningen Case

At the start of the development of a new regional plan for the province of Groningen in the summer of 2006, the circumstances were analysed. In the starting document (Huyink 2006) of the planning process three pillars were defined: economic developments, demographic changes and climate change. By the end of 2006 two events happened, which increased the political sense of urgency. The first event took place in the night of November 1, 2006: In front of the Groningen the highest sea water level ever was measured. Some (small) urban areas were flooded and at several places dikes were almost breaking through. Despite the fact that there were no casualties and the damage caused was small, the event functioned like a wake up call for regional politicians. The second event was the presentation in autumn 2006 of the movie 'An inconvenient truth' by Al Gore. The mass-media attention the movie caused generated public attention for the issue of climate change and increased the awareness among the public, but also among politicians. People became aware of the turbulent environment they live in, the long-term changes that might be happening in the future and the possible risks that are connected with these changes. This resulted in political urgency to increase the resilience of society and the spatial system, using the new regional plan.

The design of the regional plan was carried out in three phases: The analysis, the interaction and the reflection. Every phase was finished with a political document. The role of climate change in the process is shown in Fig. 5.11.

In the analysis, the long-term changes were identified and the potential impact on the provincial area was defined (understanding the system). In the second phase the acceptability of risks was discussed and the spatial claims (quantitative) were

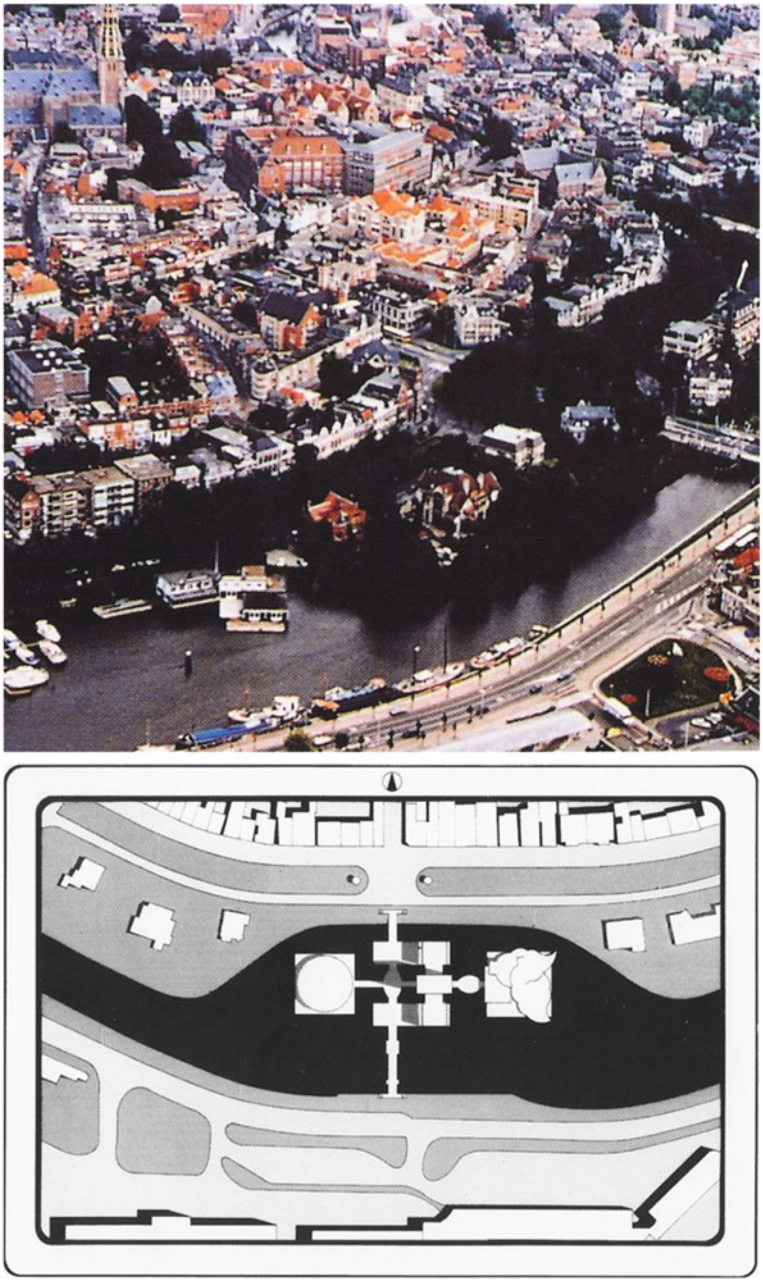


Fig. 5.9 The Groninger Museum positioned in the Verbindingskanaalzone, before (*left*) and after (*right*)

Fig. 5.10 The Groningen Museum (*Picture* © Rob Roggema)

defined (measurable input in 'tame' planning system). In the final phase the strategic interventions with the capacity to increase resilience, were described.

5.3.1 Understanding the System: Mapping Climate and Energy Potentials

In order to understand the existing system and explore the way turbulence causing factors like climate change and energy-supply function a method of mapping the potentials was developed (Van den Dobbelsteen et al. 2007). This mapping method was used for energy as well as for climate potentials. The key-factors, which are crucial for spatial planning were defined for climate as well as for energy and put subsequently on maps. The climate change factors, which are of special importance for the Groningen situation, are the future changes in precipitation and the possible sea level rise scenarios. The energy potentials focus on the potential energy production from renewable resources. Therefore, solar, wind, geothermal, hydro and biomass potentials are mapped.

Precipitation

The possible changes in future precipitation amounts and patterns are shown in Fig. 5.12. The maps show the possible changes for Groningen and Drenthe provinces (Alterra 2008) in 2050 in two KNMI'06 scenarios (KNMI 2006) for the winter and summer period.

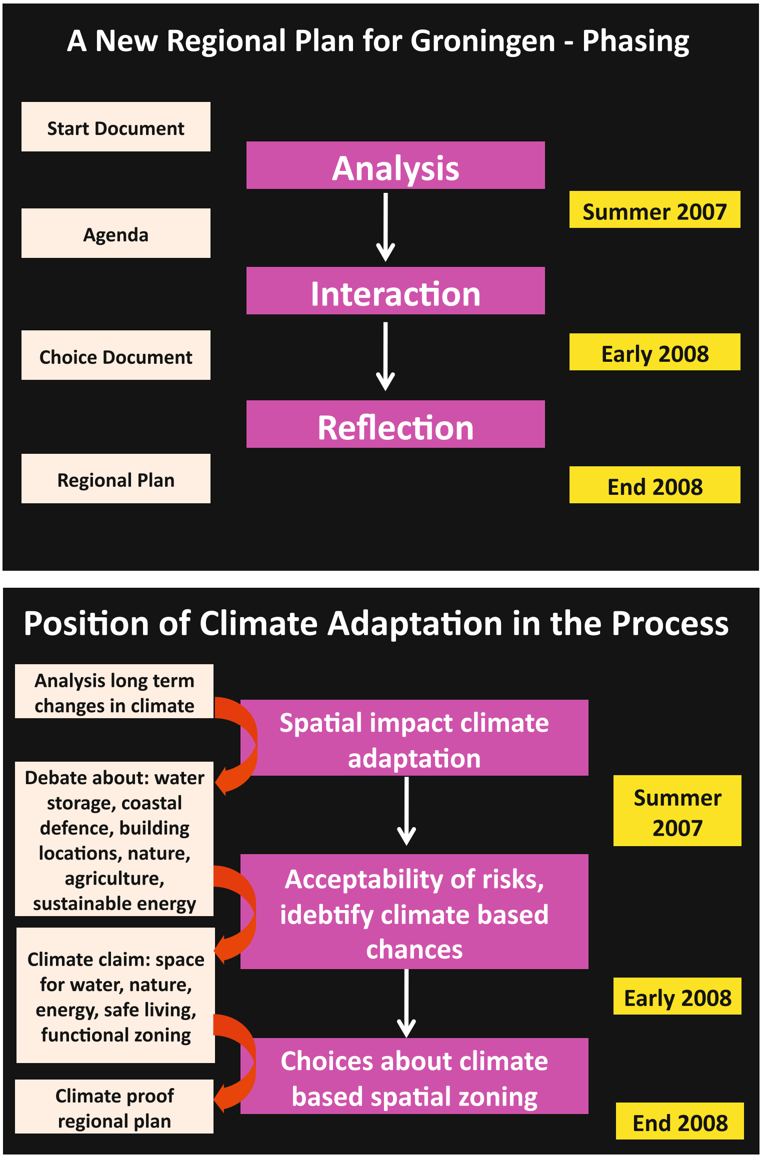


Fig. 5.11 Planning process and role of climate change (Roggema 2007b)

The main conclusions of the precipitation-analysis are:

1. In the summer period drought will most likely increase. In the 'dry' scenario of the KNMI (W+) in the eastern part of the provinces (the Peat Colonies) drought becomes a serious problem. Nowadays, water shortage in this area is already a problem. Currently, the inlet of water from the IJssel Lake solves this problem.

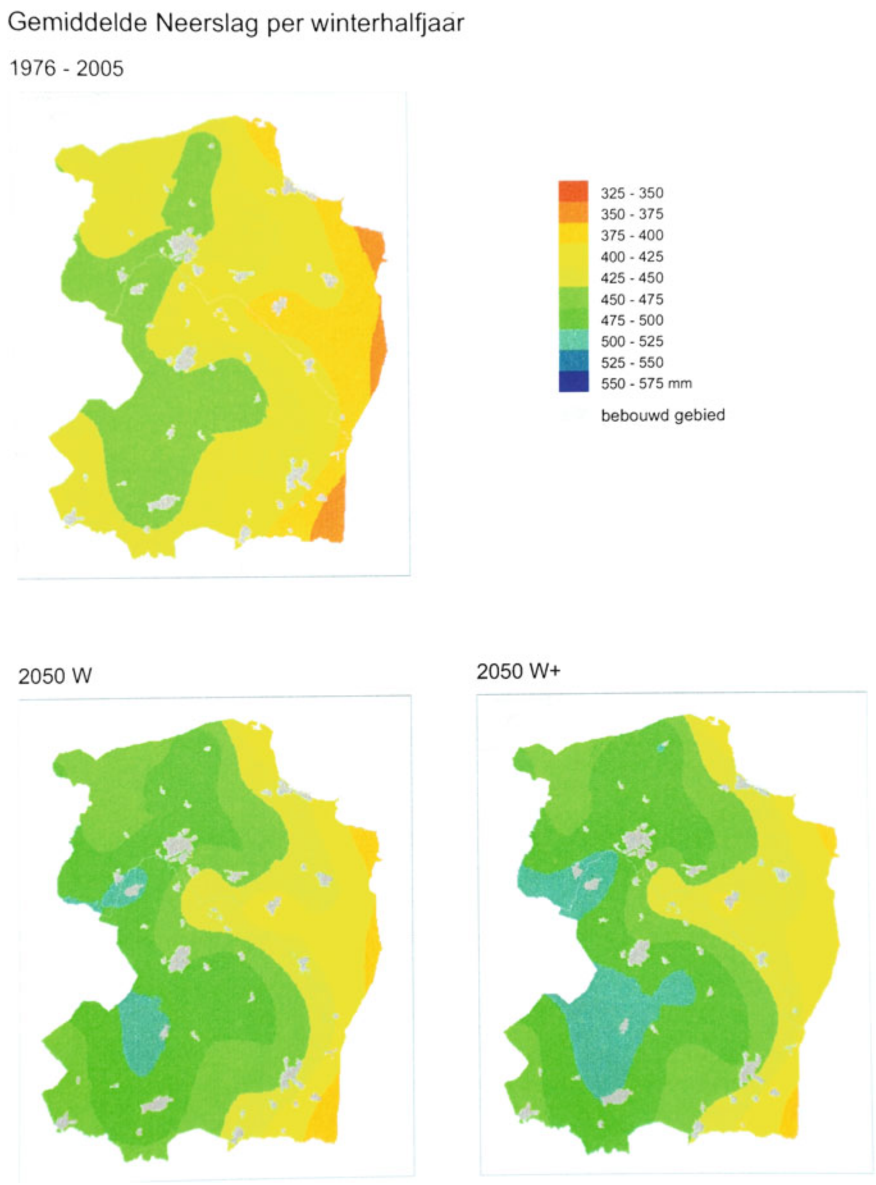


Fig. 5.12 Precipitation in the winter and summer 6-month period (1976–2005, W-scenario and W+-scenario) (Alterra 2008)

The question for the future will be if this water is still available and if the quality of the water is good enough. The problem of water shortage and uncertainty of supply will increase in the future, due to longer dry periods in summer, which are caused by climate change. Another change in precipitation

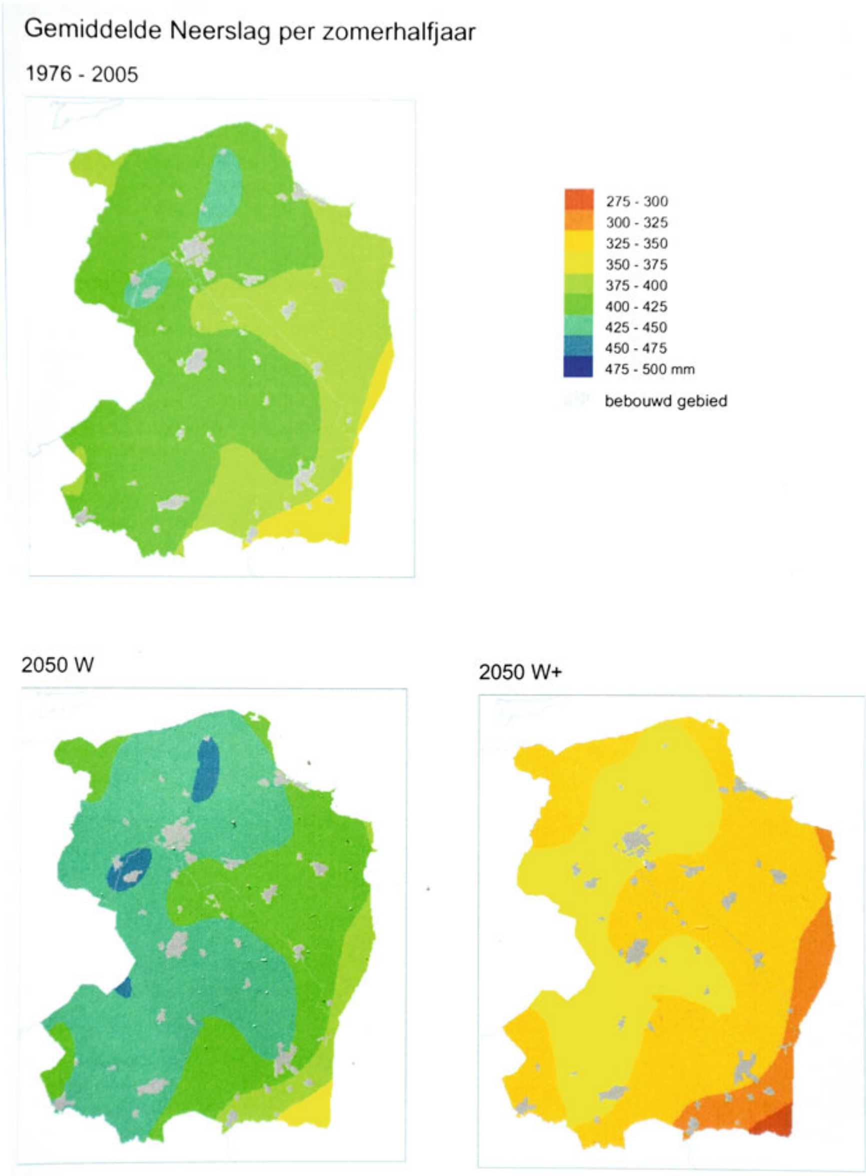


Fig. 5.12 continued

is the increased intensity of severe rain showers. This happens mostly in the summer period. When it rains in summer it pours. This effect is not visible in the maps, but it has a huge impact on water management and implies an increased risk of floods in urban areas;

2. According to the KNMI'06 scenarios (KNMI 2006), autumn, winter and spring become (much) wetter. Although a dry summer will have its 'drying' effects in autumn, which leads to average dryer autumns, the total amount of precipitation in the winter period increases. This raises questions as to how the water management must be arranged. Is an increased discharge towards the sea (with accompanying increase of pump capacity) the best solution or is an increased amount of water storage preferred? Beside the primary effects of changes in precipitationthere are also secondary effects, which are driven by these changes in precipitation
3. There is an increasing necessity to store the extra water in wet periods or pump it into the sea with heavier pumping engines;
4. In dryer periods an increasing demand for water especially in dry areas, asks for extra supply;
5. The question may be raised if agriculture and nature are capable of withstanding and surviving the longer lasting dry periods;
6. Urban areas increasingly have to cope with the impossibility to discharge the extra water, falling in the form of severe showers in the summer period, leading to periodical floods.

Sea level rise

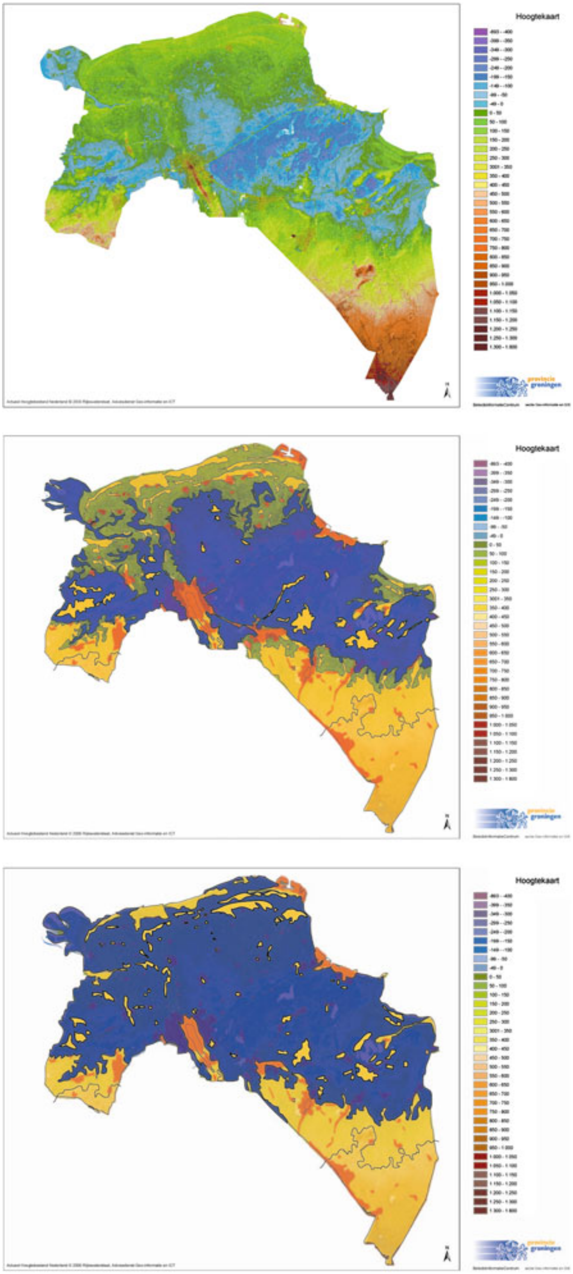
The sea level will continue to rise for the next decades and most probably for the next centuries. The speed and degree of sea level rise is dependent on the pace of melting processes of land ice on Greenland and Western Antarctica. Even if the emissions of CO_2 could be frozen at today's emissions level, the melting process would continue for the next decades. Therefore, adaptation to the rise of the sea level is inevitable. The maps (Fig. 5.13) show the possible impact of the rise of the sea level for Groningen, compared with current altitudes, in two scenarios (+50 and +150 cm). The maps show the maximum impact, because they were modelled with an undisturbed flooding by the sea after a dike breach. In reality, several obstacles (roads, little dikes) in the landscape prevent the sea from entering the land without barriers.

The maps show an indication of what might happen in the two sea level scenarios. The images are based on altitude lines and do not take into account the real circumstances in which a breakthrough takes place, namely when the sea level is much higher than normal (spring tide) and heavy rain and wind are present. Also, the map does not show the positive effect of good maintenance of dikes in order to keep them strong, which makes a breakthrough less likely to happen. On the other hand, the impact of a much faster melting land ice, leading to possible sea level rises of 3 m (Gore 2006) or up to 10 m (Carlson 2006) above the current level, is not visualised in the maps either.

Based on these maps a couple of conclusions can be drawn:

1. The southern parts of the province (Peat Colonies, Westerwolde, Southern Western-quarter) and the city of Groningen are the highest parts of the province. In these areas flood risk is low. Naturally, a sea level rise of 3 m or more would place these areas at risk as well;

Fig. 5.13 Flooding according to altitude lines (current situation (*left*), 50 cm sea level rise (*centre*) and 150 cm (*right*), (Roggema 2007a)



2. The industrial areas of Eems-harbour and Delfzijl are located at artificially constructed higher levels. These areas are relatively safe, even in a more extreme sea level rise scenario;

3. Though not visible in the maps, the salinity of agricultural land along the coast increases, due to the sea level rise, which results in increased seepage;
4. The lower and wetter parts of the province show a spatial connection between Lauwers Lake and Dollard. This connection, together with the brook system in Drenthe is potentially the most important wet ecological structure for the future. Here, nature is able to survive the longer periods of drought.

Another effect of sea level rise is the possible disappearance of parts of sandbanks in the Wadden Sea. Stive (De Boo 2005) expects that a fast sea level rise, up to 60 cm in this century, will lead to an inability of the sedimentation process to supply the sandbanks with enough sand, which results in the drowning of the sandbanks. It is estimated that in this case 50 % of the sandbanks will have disappeared within 40 years from now.

Energy potentials

Usually the local strengths of an area to use the available energy potentials are neglected in regional and urban planning. However, these potentials may well be used to generate energy and supply the local energy system. In order to find the local and regional potentials, energy potential maps can be drawn (Fig. 5.14).

This method was developed in the Grounds for Change project. A potential map is drawn for every sustainable source of energy (Fig. 5.14) (Van den Dobbelsteen et al. 2006). The potential map for solar energy shows that on average the most sunshine hours are received in the North Western part of the region. The wind potential map shows the average wind force in the region (in Beaufort), indicating high potentials near the coastline. The region offers various opportunities for the use of water in the energy cycle: an osmosis plant at the closure dike (Afsluitdijk), a tidal plant in the former sea inlet of the Lauwers Lake, osmosis plants at the boundaries of salt and fresh water in the Eemsdelta area and plants and heat pumps at the edge of the Drenthe plateau. The biomass potential map shows an interesting patchwork of agriculture, forests, lakeshore plants and domestic waste. All of these (waste) resources can be made useful to produce energy. The map with underground potential for gas (purple) and oil (red) shows the possibilities to use the underground for hot geothermal water or CO_2 storage.

If all potential maps are combined into one integrated map, the energy mix for each specific area can be determined. For every location, the energy mix map shows the optimal combination of sustainable energy resources.

The summed up areas with specific energy-combinations form an underlying regional 'energy'-layer in planning processes. This layer functions as a base for spatial decisions. Mapping the energy potentials makes them available for spatial planning and indicates the specific identities of different areas. Decision makers can make use of this map as a basis for decisions on the development of new areas or the abandonment of certain places. In order to make full use of the sustainable potentials, the traditional (grid-based) solutions, which are bound to become less secure in the future, becomes less useful. Innovative local production and supply of renewable energy resources requires a more locally based system of energy

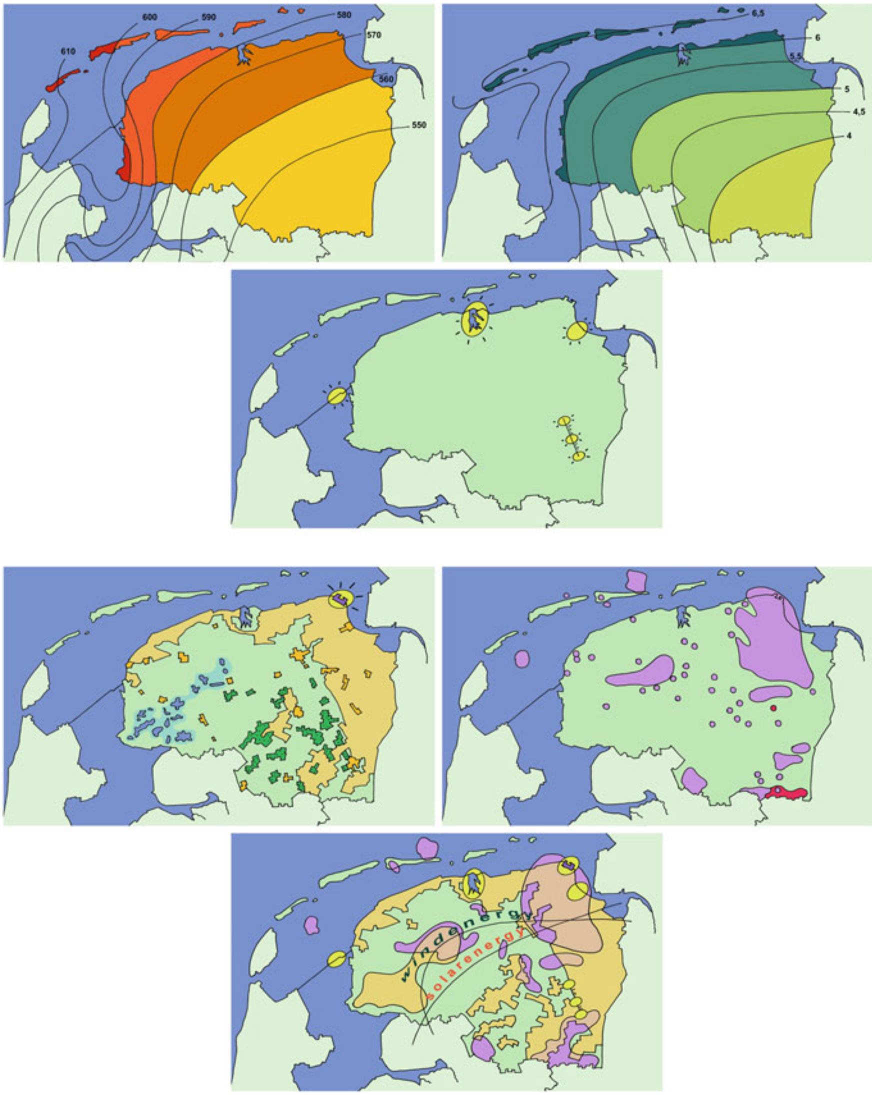


Fig. 5.14 Energy potential maps: from *left* to *right* and from *top* to *bottom*: solar, wind, hydropower, biomass and geothermal, and the energy mix map (Roggema et al. 2006)

supply, which might differ from place to place, enabling every (sub-) region to develop its own qualities. This results in a map with several distinct energy landscapes (Fig. 5.15).

These energy landscapes were taken as the base for further research on the use and exact potentials of different resources for the province of Groningen. The collected and potentials of solar, wind, hydro, geothermal and biomass resources

Fig. 5.15 Energy-landscapes in Northern Netherlands (Roggema et al. 2006)

resulted in an intervention map for the provincial level (Fig. 5.16). All sustainable energy measures are combined in this map (Van den Dobbelsteen et al. 2007). New areas for development of living areas are emerging near the Lauwers Lake and the industrial zone (in red). The central lower area might be used to gain energy from hydropower and alongside the highway a biomass-corridor can be developed, where biomass is transported to and energy is produced.

5.3.2 Improving Resilience: Use of Swarm Planning Paradigm

The next step in the planning process was the transition of the knowledge about the regional climate and energy system into interventions and ideas, which might improve the resilience of the region. Two ways were explored.

The first way aimed at integrating the potential maps into a climate proof map of Groningen: the idea map. This map shows an end-image of a climate proof province. It can be seen as a desired future on the long term and does not give insights in the way this future might be reached. The map functioned as a source for debate and gave direction to the planning process.

The second way focused on the definition of strategic interventions, which should be introduced today in order to start the change of the region towards

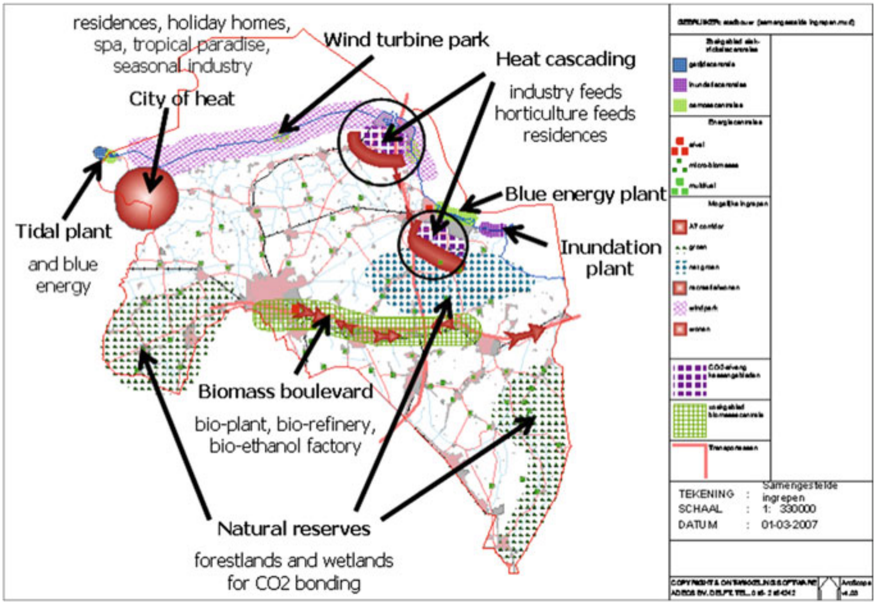


Fig. 5.16 The energy intervention map for the province of Groningen (Van den Dobbelsteen et al. 2007)

higher resilience. These strategic interventions imply and stimulate the desired changes on the long term. These interventions can be seen as the first steps towards realisation of a climate proof province.

Idea-map Climate Adapted Groningen

Climate analyses (KNMI 2006; Alterra 2008; Roggema 2007a) and the effects on existing functions (MNP 2005) are integrated in an Idea-map for an adaptive Groningen (Fig. 5.17) (Roggema 2007a). This map represents a future vision on a climate proof Groningen with spatial measures. The following principles are part of the Idea-map:

1. In the lowest parts of the province, water is stored. Even in dryer periods, water is kept in this lowest area and creates wet circumstances in a natural way. This enables nature to develop a robust ecological connection between the Dollard and Lauwers Lake. Existing brooks discharge their water from the higher grounds on the Drenthe plateau. In the ecological zone existing as well as colonising species are able to find suitable habitats;
2. The water storage areas also function as the water resource to provide agriculture with enough water of good quality. This is especially relevant in the Peat Colonies, where drought has the largest impact. The water can be transported towards the agricultural ground by making use of the existing canal system in the Colonies. The availability of water is essential for the potato starch production in the area. The supply with clean water is necessary from a

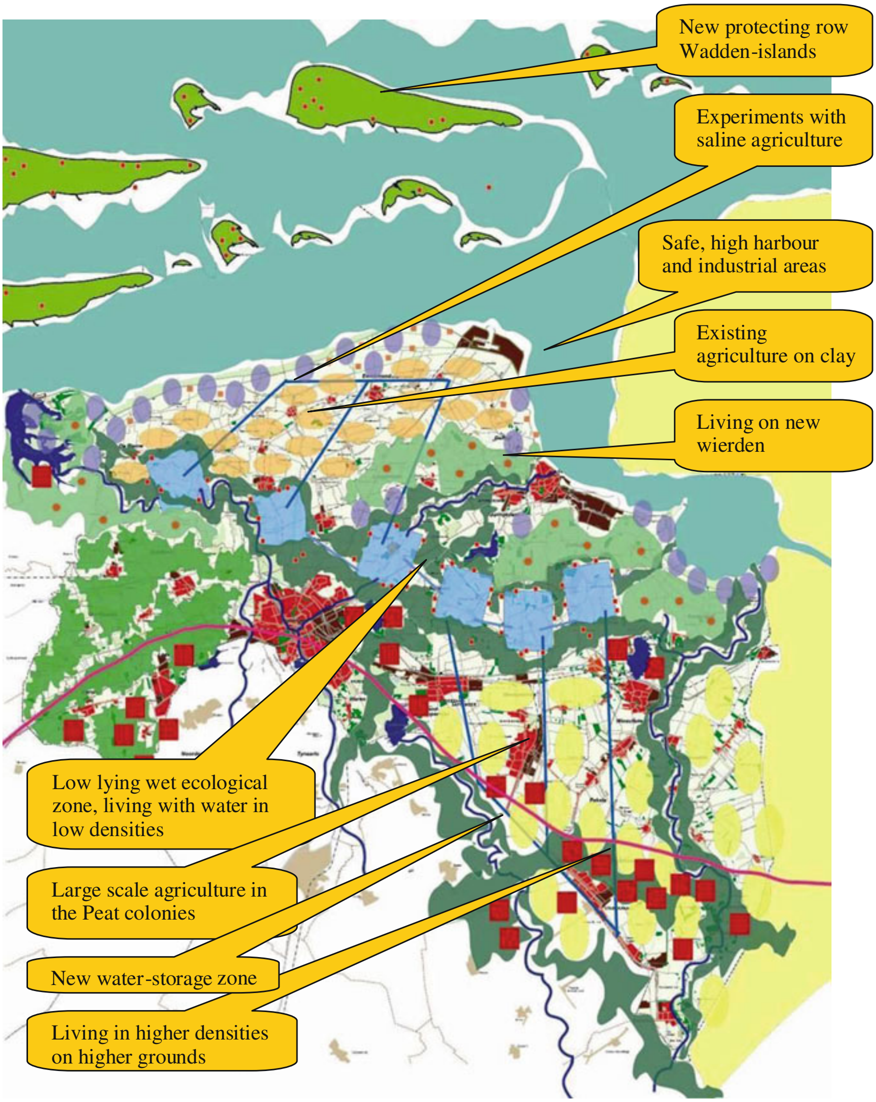


Fig. 5.17 Idea-map climate adapted Groningen (Roggema 2007a)

quantitative point of view, but is also needed for a qualitative reason. In the 'dry' KNMI-scenarios, the groundwater level will drop and might even become saline. Addition of sweet water prevents the available water for agricultural use from becoming useless;

3. The salinity along the northern coastal zone increases, due to the sea level rise and the increased salty seepage. This makes this area suitable for saline agriculture and aquacultures;

4. Near Lauwers Lake, Dollard and around Delfzijl space is created to inundate water from the sea into ‘climate buffers’ (Bureau Stroming 2006). A brackish environment emerges. The combination of salt and sweet water makes it possible to generate energy in an osmosis plant;
5. In front of the Northern Coast new Wadden Islands are created to protect the province, to develop nature and to provide development locations for living and recreation.
6. The safest parts in the province to create living areas are found in higher elevated areas: Around Leek and the city of Groningen and in the southern part of the Peat Colonies and Westerwolde.

5.3.3 Strategic Interventions: The Groningen Impulses

The second way to improve the preparation for turbulent environments is to place strategic interventions. These interventions are not meant to define exactly an end state of the area, but they mark the start of processes, which emerge from that point on by themselves and influence a larger area. The impact of the intervention may be predicted and needs to generate more resilience in the area, but the exact future developments in the area are not defined. This approach makes it possible for stakeholders, involved parties and citizens to co-operate and contribute to the development of the area. The objective of this approach is to increase resilience in the entire province. This is realised by loosening the fixed state of the existing situation. In most of the situations this fixed status is the cause of large risks. By introducing the flexibility to deal with future threats or challenges and creating the space for the impact of these threats and developments, society is better prepared and already used to the situation and possible events, which occur in the future. The windows of Groningen (Fig. 3.8) show several of these opportunities, where loosening the tight and normative rules enable the area to react proactively, increase preparedness and are able to return to their original state after a change more easily: improved resilience.

These strategic interventions are the impulses, which are added to the area and adjusting the area without changing its function. The impulses make use of the capacity the complex adaptive spatial system has (if enough space can be created to do so) to adjust itself to new circumstances and developments. The interventions function like the simple impulses, which are capable of reshaping a swarm of birds: constantly transforming, but staying the same swarm of birds.

In the Groningen case several of these interventions are proposed (Fig. 5.18). They have in common that a single intervention opens the way to an indirect effect in a larger area.

1. Heightening the closure dam of the Lauwers Lake enables the area to store more rainwater in winter, influencing the entire stream area of the Reitdiep;

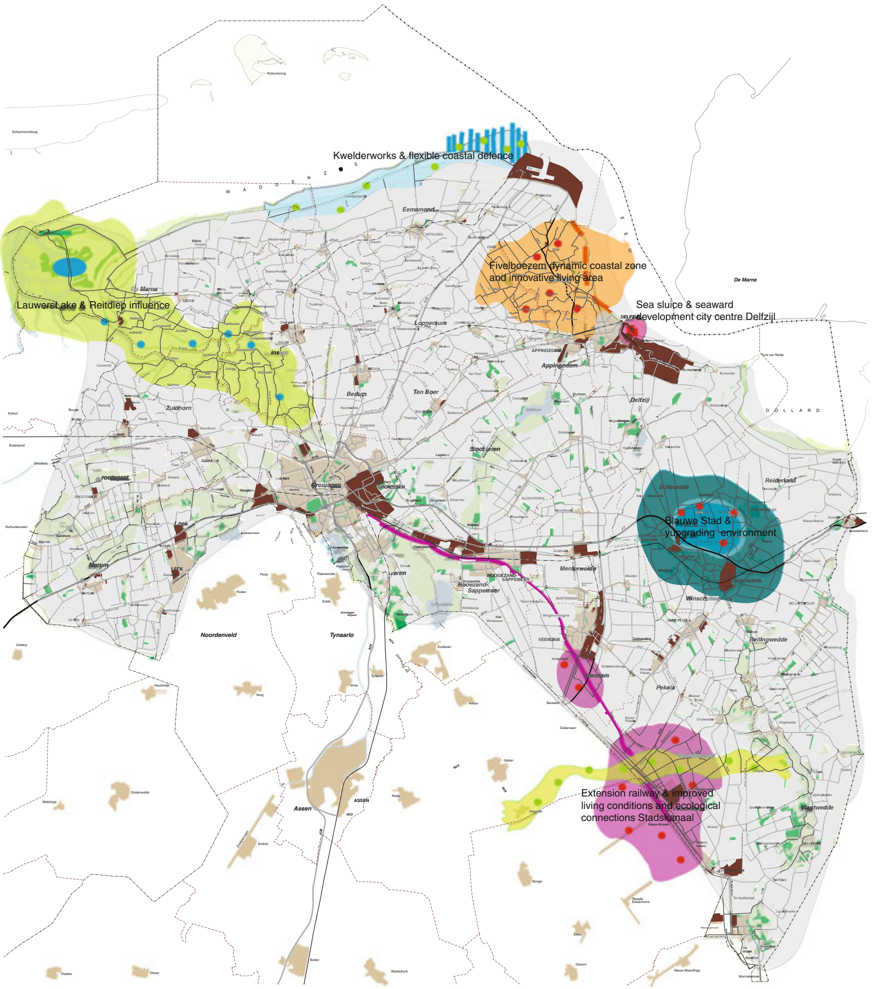


Fig. 5.18 Windows of Groningen, strategic interventions

2. Creating new kwelderworks near the Eems harbour enables the Wadden Sea to create new arable land, which may be used as wished in the future. For agricultural purposes, as an industrial area or an ecological zone;
3. Perforating the dike between the Eems harbour and Delfzijl opens the opportunity to create a dynamic coastal system, which is able to supply the hinterland with sand, that sedimentates here. The sand lets the soil rise at the same pace as the sea level or faster and an innovative way of living can be introduced;
4. Repositioning the Sea sluice of Delfzijl outside the city makes it possible to create a safer storm surge and offers Delfzijl the chance to develop its waterfront towards the sea;

5. Generation of a luxurious living area in a back-dropped surrounding makes it possible to extend the capacity for water storage and influences the living standards of these surroundings positively;
6. The introduction of a new railroad, which connects the City of Groningen with the Peat Colonies, enables the southern part of the province to develop a robust ecological corridor, which gives space to shifting ecological habitats and makes an interesting living area possible amidst nature.

A couple of these interventions are described in more detail.

Fresh water storage in Lauwers Lake

The first example of a strategic intervention is dealing with the rising sea level and the upcoming shortage of drinking water (Meliefste et al. 2008). In the design fresh water will be stored in the Lauwers Lake (Fig. 5.19) by heightening the level of the water in the Lake. This higher water level makes it possible to keep up with the risen sea level and the water board is still able to let water flow into the sea without pumping. As a result of the risen water level the entire water system (the swarm) of Groningen is forced to adjust itself. The risen water level in Lauwers Lake also implies the rise of water level in the Reitdiep stream and other small canals and brooks. The capacity to store rainwater is increased by this simple intervention, which helps to deal with heavy rain showers and potential flooding in villages and towns. In other words, by solving the first problem and intervene in the Lauwers Lake, the entire region is challenged to adapt effectively to the effects of climate change.

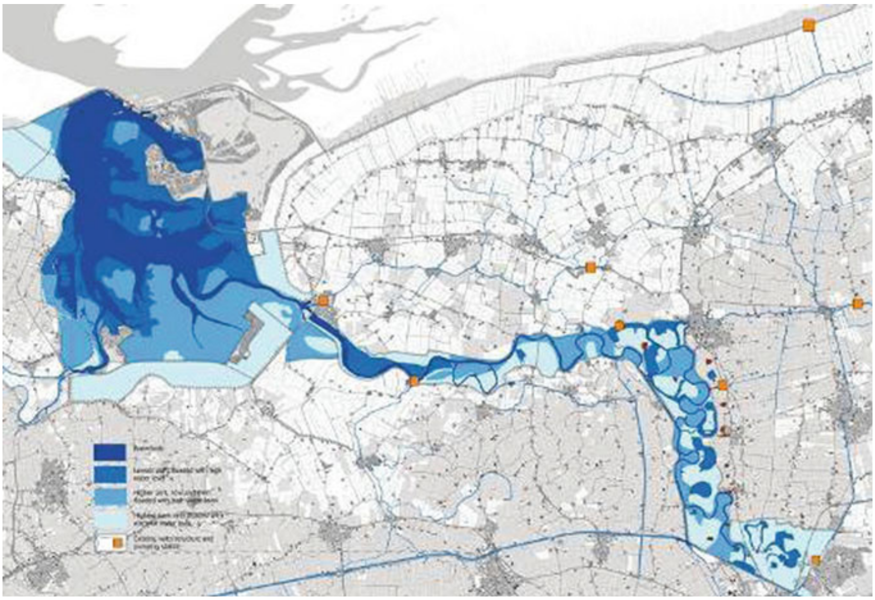


Fig. 5.19 Proposal for fresh water storage in Lauwers lake (Meliefste et al. 2008)

Kwelderworks Eemsdike

The second strategic intervention is to re-introduce old-fashioned kwelderworks in front of the Groningen coast (Fig. 5.20) and especially in front of the weakest and most vulnerable part near the Eems harbour (Meliefste et al. 2008). The kwelderworks start natural processes, which fixate sand and mud. These processes enable the soil to slowly grow along with the rising sea level until it finally rises above the sea level. Because of this, the kwelderworks are capable of protecting the shore. The offensive way the kwelderworks near the Eems harbour are positioned creates extra space. This newly created land (the swarm) is not meant for a specific purpose. This choice can be made at a later stage. When new arable land is needed it is possible to turn the area into agriculture, but when the economic development of the Eems harbour requires expansion of industrial area it is also possible. And when the ecological quality of the Wadden Sea requires extra space, it may be realised on this location as well. The introduction of the kwelderworks implies a better protection of the coast and makes it possible to postpone the choice what to do with the reclaimed land until it is needed.

Blauwe Stad

The eastern part of the Province of Groningen has traditionally been the poorest region in the Netherlands with pervasively high unemployment, low levels of education and poverty. People who could, left the area. Due to heavier rainfall the need to find water storage in the lowest parts of the province is urgent. The Blauwe Stad area is one of the lowest places in the province and this fact, in combination

Fig. 5.20 Kwelderworks near Eems harbour (Meliefste et al. 2008)

Fig. 5.21 Blauwe Stad implemented in the landscape of eastern Groningen

with the back-dropped character of the area, has led to a third strategic intervention: the introduction of a new luxurious village around a lake, the Blauwe Stad (Fig. 5.21). This intervention resulted in the upgrading of the entire area (the swarm) around the village, where economic development improved, the amount and quality of amenities increased, the infrastructure is improved, the possibilities to deal with large amounts of water is increased and unemployment is decreased. The indirect development of the area evolves by itself, after the impulse of the Blauwe Stad has been done.

Dynamic coast Fivelboezem

The coastline between Eems harbour and Delfzijl is the most vulnerable in the province. In the hinterland a second dike supports almost every dike piece in the province. This second dike is absent in this area. A breakthrough here causes a flood that would reach the province capital within 24 h. The economic damage is largest if this breakthrough happens. This strategic intervention consists of the perforation of the existing sea dike and the creation of an extra dike in the hinterland (Fig. 5.22). The area between the old and new dike will be flooded semi-permanent. In this area dynamic circumstances emerge, both from an ecological point of view (brackish, changing water levels) as from a human perspective (living on newly built wierden (artificial hills), changes in wet and dry surroundings). Society will have the chance to adapt to future threats, like a flood, because the area is designed for it. After water enters the area, it leaves and the area can turn back into its old position very easily. Moreover, in the future it might be difficult to define what the original state of the area was, covered with water or not?

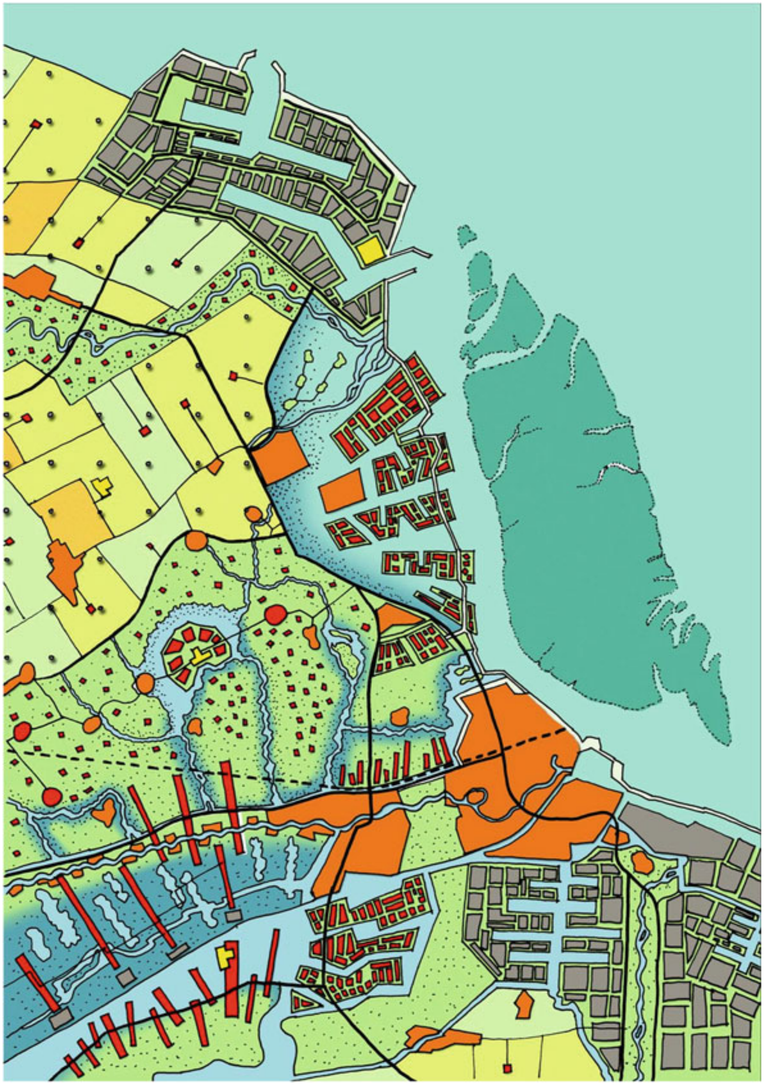


Fig. 5.22 Dynamic coastal development Fivelboezem (Roggema et al. 2006; drawing: Bosch and Slabbers)

5.3.4 Steer the Swarm

The existing spatial planning system has difficulties creating those effective interventions, which are capable of dealing with increasing turbulent circumstances (like the uncertainty of energy supply and rising energy prices and changes in climate). These aspects are turbulent because they are long-term, uncertain and play a role in the far future. In traditional terms: they cannot be planned, but will occur as surprises.

It is possible to deal with these uncertainties and create resilient areas if areas are given the opportunity and space to change along with sudden changes and at the same time build experience today which is required for future threats and challenges. If the area is given this opportunity the resilience will be improved. The area will be capable of dealing with the effects, threats and challenges these future changes imply. When the area is given the possibility to change with the changes, the spatial order is not fixed in a certain state, but the spatial system is designed in a way that it is capable to change its patterns, its 'being' and the way it looks according to the requirements of that date or the changing, unexpected demands of the future.

In the current 'fixed' spatial planning system almost no spatial flexibility is included. Because of that there is just no space available to create a buffer to adapt to fast changing circumstances more easily and to increase preparedness.

The planning system of the future has to include steering principles, which enable areas to adapt more easily and change its spatial patterns as required by future threats and challenges. These steering principles include, according to the Groningen example two elements: space to change and strategic interventions. These elements differ from place to place, depending on the characteristics of the natural system and spatial identity. Thus, the swarm in the area can be steered in a desired direction of higher resilience.

Depending on the specific qualities of the area the spatial regime can be distinguished. The combination of spatial and natural character of the system in combination with a well-defined intervention creates the resilience regime for that area. In abstract terms, a 'Mondrian' typology can be derived (Fig. 5.23) as in the concept Atlas Groningen is developed (Roggema and Huyink 2007).

5.4 The Groningen Case Discussed

Evaluating the Groningen case several remarks can be made. The development and usage of innovative methods as well as the applicability in practice will be discussed.

5.4.1 Mapping

The method to map Climate change and energy potential information gives good results in understanding the spatial potentials the regional system contains. The results of the mapping method can be used in several ways. First of all the size of potentials can be derived from the maps, sometimes measured in covered area or otherwise in potential energy production. The second use of the maps is that they

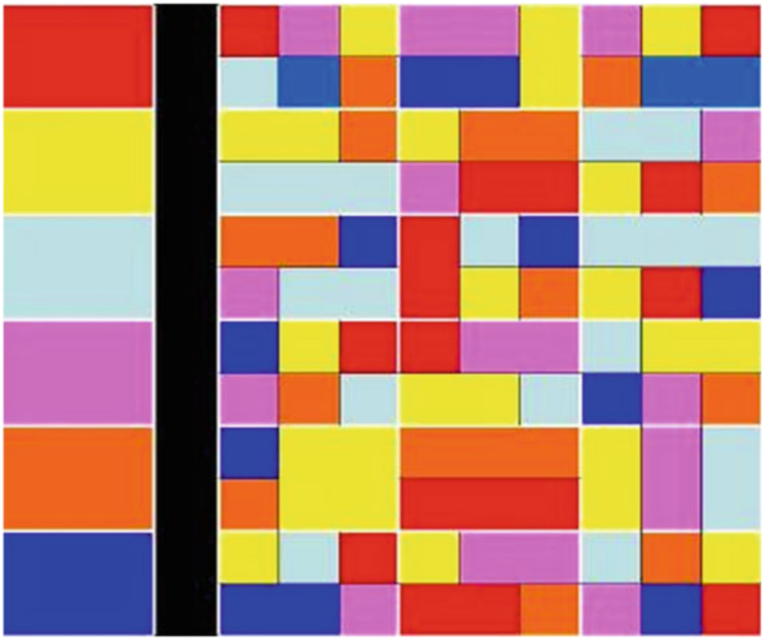


Fig. 5.23 A 'Mondrian' combination of interventions (*left column*) and identities (*right field*) (Roggema 2007a)

function as a layer to base policies and designs on. Taken the potential maps as a base design interventions or measures can be found. The final way they can be used is as an inspiration for integration. The maps offer information which was not available in earlier planning processes.

5.4.2 Idea Map

The constructed idea-map for an adaptive Groningen functioned as a trigger for debate. However, the question may be posed if the content of the map is too integrated and coherent. It seems that the idea-map is more or less the same as an end image of a future Groningen, but then an adaptive one. The idea-map is an interesting starter for discussion, but it contains the risk of stepping into the same pitfalls as the existing planning practice: a far to fixed image of the future is translated into strict spatial measures, while the future becomes increasingly unpredictable.

5.4.3 Interventions

The definition of strategic interventions in combination with the creation of flexible space in the area in order to give space to unpredicted developments can be an approach, which is capable of both dealing with an uncertain and turbulent future as well as creating the spatial flexibility to give stakeholders the power to intervene and steer towards a more resilient future in the area. The main question remains which intervention has the best results, i.e. leads to higher resilience of the area.

5.4.4 In the Real World

Although these innovations were developed during the planning process of the new regional plan for Groningen, the question is if and how the developed interventions will be realised. Despite the fact that decision makers decided to define four area assignments, where integrated area development should take place, and these areas are the same as the areas where interventions are proposed, it is still uncertain if these interventions will be part of the area development. This might lead to the conclusion that the thinking on improving resilience is not translated into political objectives yet. The existing planning process is still a tame process, where the problem analysis and the derived solutions are the objective instead of aiming to increase the adaptive capacity of spatial systems, enhancing an increased resilience. The question is if the sense of urgency to prepare for future turbulence is high enough among decision makers of today.

5.5 Conclusions

The resilience of areas to deal with a turbulent future may be improved by applying the principles as defined in the theory of complex adaptive systems to spatial planning methods. So far, there are not many examples of spatial planning, which use this theoretical background in planning practices. The Groningen case shows that a region can be made more resilient and better able to deal with turbulence when the principles of complexity and resilience are used. Usage of these principles may change the planning practice towards a more adaptive and flexible form of planning. And because every region will have to deal with more turbulent circumstances in the future it may be concluded that the first experience with this new planning paradigm (swarm planning) can be used in other regions as well.

Societies are better prepared for a turbulent future if strategic interventions are included and in a spatial sense the space and conditions are created to adapt in planning system. If the space is created, the capacity of stakeholders and citizens to contribute to the development of the spatial system in the area can be implemented more easily. When strategic interventions are combined with the spatial conditions to adapt to future threats and challenges and when the area is given the time and opportunity to get used to dealing with future threats and challenges, resilience is improved.

When the interventions are well defined, they are able to steer the swarm. Swarm planning is capable of starting adaptive processes, which makes it easier to adapt society to emerging turbulent circumstances. If a simple intervention has a wider spatial impact the measure is more powerful and potentially has a higher impact on resilience.

When the possible effects of turbulent environments are included into the design and spatial layout of the area these future threats and challenges are no longer a surprise, but are rehearsed and have become familiar situations: the area has adapted before it is confronted with the changes.

In order to increase resilience of a region the 'adaptive' principles of swarm planning must be applied. Therefore, swarm planning has to learn from complex adaptive systems theory. The following principles can be defined:

1. The regional spatial system must be seen as a complex adaptive system;
2. Improvement of resilience can be reached by implementing strategic interventions;
3. The definition of the elements of complex adaptive systems for the local situation is essential as well as the way in which they can increase the impact of an intervention;
4. A large pool of genes (measures, inhabitants, functions), some simple rules and enlargement of trails (improving impact) are the start of long-term changes;
5. Potential mapping of climate and energy aspects may be used to discover those genes of the region, the trails and the simple rules, which are able to create a climate-proof region. The spatial translation of these potentials into isolated spatial typologies, which may play a major role in interconnecting in a future society, is not defined yet. In history, the sidewalks in a neighbourhood functioned like the interconnection platform, but current and future interconnections are presumably made in a different way and at different places. The transport system, the sidewalk, the stranger (the "away-from-the-average"?) and the 'city' of our time are yet to be discovered;
6. Swarm planning (large pool), with a well-defined (simple rule) impulse (which is able to enlarge the trail/impact) may be able to steer a region into the desired direction.

In Fig. 5.1, the mutual relations between all facets of the case are visualised. When large impact changes, like climate change, an Internet society or uncertain energy supply are, are about to happen, they imply an increasing turbulence. These developments influence the regional spatial system. In order to understand this regional system better, the principles and characteristics of complex adaptive systems can be of help as well as the regional mapping of climate and energy potentials. Lessons learned from adaptive systems, combined with the regional energy and climate characteristics, offer the opportunity to find the most suitable strategic interventions and localisation of flexible space. These two elements lead to increased resilience of the regional spatial system, if used in the right spatial planning system. The increase of resilience in the regional spatial system implies that the region will be better equipped to deal with the described turbulence.

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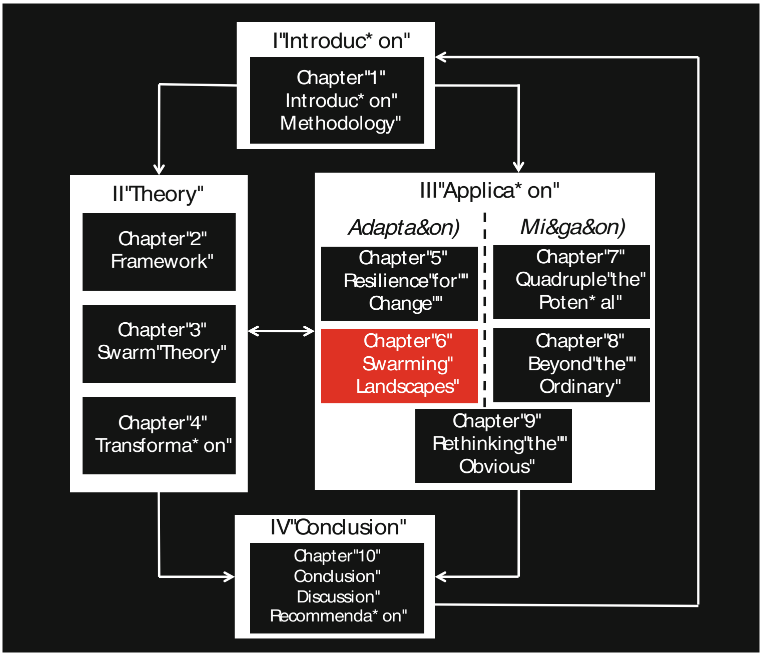
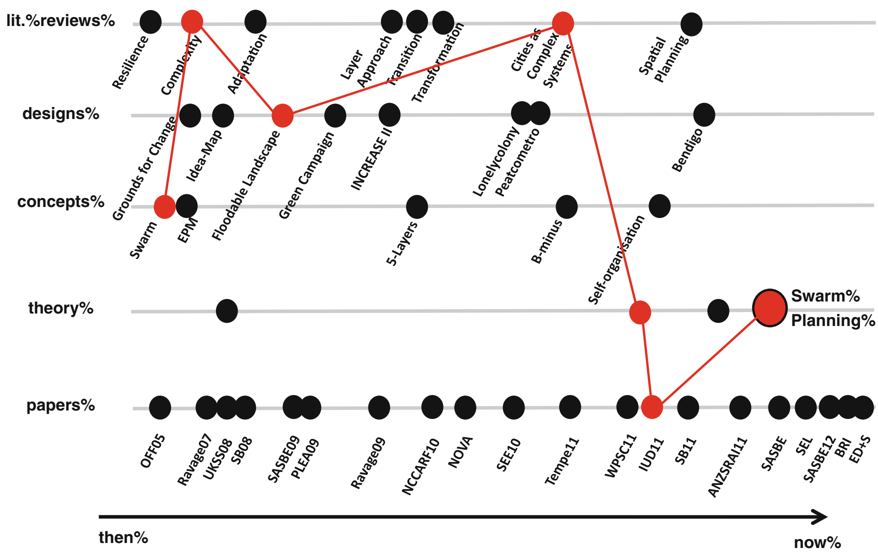
The Bridge: Five–Six



This chapter used complexity and resilience thinking to develop a future design that is more capable of dealing with uncertainty. In Chap. 6 this thinking is further elaborated. The properties of Complex Adaptive Systems are translated into spatial planning practice. Self-organisation, emergence and adaptive capacity are used as the basic principles of design, thus increasing the flexibility, diversity and resilience in urban and rural systems. In this chapter, these properties are used to design the Floodable Landscape, a design that deals with uncertainties and is a future spatial vision that is capable of dealing with unknown changes and surprises in weather and climate. It is a 'Swarming Landscape', not only increasing the resilience of cities and landscapes, but also provides an attractive and imaginable spatial future. This chapter/article is published in the proceedings of the 4th International Urban Design Conference 2011.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Transformation
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Spatial Planning
Grounds for Change
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Floodable Landscape
Green Campaign
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Lonelycolony
Peatcometro
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NOVA
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IUD11
SB11
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Chapter 6
Swarming Landscapes, New Pathways for Resilient Cities

6.1 Introduction

Spatial planning and climate change science are part of a complex and uncertain context. The general response to this, and this can be seen throughout both the spatial planning and the climate change community, is to try to reduce uncertainty by introducing more procedures, developing more detailed models and increasing control of processes. However, gaining more detailed knowledge does not always increase certainty, or as Kevin Trenberth (2010) puts it: 'More knowledge less certainty'. Both spatial planning and climate change, even more so if the two are linked, could gain from introducing self-organising principles. In order to be able to do so, the spatial system needs to be understood as a complex adaptive system, in which processes of self-organisation and emergence create ever changing spatial patterns, which, when used purposefully, will increase the system's capability to respond effectively to unexpected change and uncertainty, for instance as a result of climate change. Providing the individual spatial elements in the landscape with a surplus of 'technical skills' will enable these spatial entities to self-organise and adapt more easily, thereby collaboratively increasing the adaptive capacity of the system. In order to create the conditions, which allow these self-organising processes to take place, current spatial planning practice needs to let go of its preference to regard spatial systems as being simple and problems as being tame. Complex Adaptive problems, such as climate change, cannot be dealt with within the current spatial planning framework. They require fundamental rethinking of the models underpinning spatial planning and introducing a new planning methodology. Swarm Planning claims to offer this methodology, using the dynamics of swarms as a metaphor. The behavioural patterns of swarms in nature are governed by the principles of self-organisation and emergence, rather than being planned

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R. Roggema, *Swarm Planning*, Springer Theses, DOI: 10.1007/978-94-007-7152-9_6,

and controlled by an outside authority. When these principles are built into a complex spatial system, the system can start displaying the properties of a swarm: responding to interventions and impulses it will change its shape, but not its content. The elements that make up the system will still be the same, yet they will interact in way that is more responsive to changing and uncertain circumstances, thereby increasing its adaptive capacity. The purpose of this chapter is to develop Swarm Planning as a planning methodology, which is better equipped to deal with uncertainties and to effectively plan for the complex problem of climate change. This new methodology looks at spatial systems as complex adaptive systems and uses the properties of these systems spatially to increase the resilience and adaptive capacity of the system. The chapter will first examine different views on dealing with uncertainty, it will then describe the properties of swarms and complex adaptive systems and their applicability to a Swarm Planning method and the chapter will conclude with describing a Swarm Planning design, illuminating the potential benefits.

6.2 Dealing with Uncertainty

Climate change and climate adaptation are often linked with uncertainty. As cited by the Global Commons Institute (2011), WGI of the IPCC states: "Climate change, the greatest threat to mankind, is resistant to reliable methodological quantification. In many cases it is not possible to ascertain the probability of outcomes and their consequences through well-established theories with reliable and complete data. Both the risk and uncertainty of climate change require a very large degree of subjective judgement, erring on the side of precaution". People are generally averse to uncertainty and vagueness and are accordingly reluctant to take action in response. However, when uncertainty is framed positively, people have stronger intentions to act (Morton et al. 2011). Researchers describe several definitions of uncertainty (Solomon et al. 2007; Dessai and Van der Sluijs 2007). Recognised ignorance, which is different from value and structural uncertainty, addresses unpredictable uncertainties, which are related to unprecedented (climate) events, which are too few to define a probabilistic distribution (Garnaut 2008) and arise in systems that are either chaotic or not fully deterministic in nature and limits our ability to project all aspects of climate change (Solomon et al. 2007). The strategy to cope with this type of uncertainty is, instead of giving priority to reduce uncertainty, both technical and in policy (Mearns 2010; Meyer, 2011), to develop resilience and flexibility to endure effects of unpredicted events (Engau and Hoffmann 2011), accept uncertainty and expect unanticipated surprises (Dessai and Van der Sluijs 2007).

In the light of this, limits to or unavailability of climate predictions should not limit adaptation. Instead, climate adaptation strategies (Dessai and Hulme 2004; Hulme and Dessai 2008; Dessai et al. 2009), decisions (Dessai and Hulme 2007) and robust measures (Hallegatte 2009; Wilby and Dessai 2010) can be effective, even in the face of deep uncertainty[1] (Kabat 2008). It may even prove cost ineffective to wait for more precise knowledge, especially if catastrophic events, the likelihood of which is little known, are taken into consideration (Pindyck 2006).

The lack of attention to uncertainties in major adaptation research works (Adger et al. 2007, 2009) therefore does not need to worry us as the resilience approach (Dessai and Van der Sluijs 2007) offers a positive framing of uncertainty and opens the opportunity to lessen the impact of uncertainty, complexity and change, e.g. increase the resilience, through designing our cities and landscapes learning from the way swarms work together in smart groups (Miller 2010, p. 226).

6.3 Swarms

Swarms in nature have been extensively studied and the behaviour of bees, ants, birds and termites is used as an example for human interactions in organisations and society (Fisher 2009; Miller 2010). Core of these theories is that swarms function according to a couple of very simple rules[2] and perform as highly resilient systems, due to, according to Van Ginneken (2009), (1) the interactions taking place between a large number of similar and free moving 'agents', which (2) react autonomous and quick towards one another and their surrounding, resulting in (3) the development of a collective new entity and a coherent larger unity of higher order: the system is self-organising in preparing and responding to changing circumstances. It develops emerging patterns and structures, which lessen the impact of uncertainties, complexity and change. Miller (2010) defines four principles of a smart swarm: self-organisation, diversity of knowledge, indirect collaboration and adaptive mimicking (coordinate, communicate, copy). In the current timeframe of connectivity, networks and the World Wide Web these swarm characteristics are becoming more important and will increasingly shape the way we live in the future. As Bonabeau et al. (1999) have demonstrated autonomous, emerging patterns and 'parallel distributed' co-evolution will empower collective self-organisation and enhance synchronicity. These will take the place of the controlled, pre-programmed and hierarchical centralised processes as we know them to date and will give space to self-organising innovation through an interchanging occurrence of correcting and stimulating feedback loops.

In the design of our built environment swarm theories and features are very rarely used. Oosterhuis applies swarm behaviour to buildings (Oosterhuis 2006, 2011).

[1] Deep uncertainty is defined as the condition where analysts do not know or the parties to a decision cannot agree upon (1) the appropriate models to describe interactions among a system's variables, (2) the probability distributions to represent uncertainty about key parameters in the models, or (3) how to value the desirability of alternative outcomes (Lempert et al. 2003, 2006).

[2] As an example, the very simple rules in nature (for birds and fish) are (1) Stay as close as possible to the middle, (2) Move in same direction and with same speed as the others and (3) Stay 2-3 body-lengths away from neighbours.

The programming and programmatic labelling and tagging of building components enables customising buildings to temporary desires or changing demands. The fluidity of the designs represents the constant adjustability of the individual elements in the building. The use of swarm characteristics on the regional landscape scale has been subject of several publications (Roggema 2005, 2008a, b, 2009; Roggema and Van den Dobbelsteen 2007, 2008, Roggema w. De Plaa 2009). However, the spatial translation of swarm characteristics has been identified as a research gap.

6.4 Complex Adaptive Spatial Systems

As swarms are capable of self-organisation and can develop emergent patterns in order to maintain existence or deal with changes in their environments, they can be seen as complex adaptive systems. The features of this type of systems influence their resilience and adaptive capacity. Applying these features to the spatial systems in a region therefore can be useful to increase adaptive capacity and resilience of the spatial system and can make the region better equipped to deal with the potential disturbance of climatic events. However, even though cities are regarded as complex systems (Batty 2005; Allen 1996; Portugali 2000), research rarely uses the knowledge about complex adaptive systems as input for design or future thinking. As a result of this most characteristics of complex adaptive systems are not extensively defined in a spatial manner. Research on this topic has started only recently (Roggema et al. 2011, 2012) and will be elaborated on in this chapter. As a start the works of Johnson (2001) (eco-biological), Homan (2005) (organisational), De Roo (2006) (planning), Miller and Page (2007) (computational/social) and Miller (2010) (societal/decision-making) are taken. They all describe the properties of complex adaptive systems. When these properties are combined the key features of complex adaptive systems can be distilled: a complex adaptive system is able to self-organise, is diverse, contains indirect collaboration and adaptive mimicry, has the capacity to adapt (through diversity, flexibility, heterogeneity, reconfiguring, balance, and learning and storing), shows emergence in developing collective patterns, consists of a large number of individual elements, contains many interactions and is able to undergo change while retaining its basic features. In order to undergo such a change the system needs to receive a certain incentive, a tipping point (Gladwell 2000), allowing the system to jump to a different state.

When these properties are translated into spatial dimensions (Table 6.1), the following spatial elements arise: a mix of functions, a mosaic (different spatial sizes and entities) in the city and the landscape, space for natural resources, space that has not been allocated (free space), dense and connected networks, focal points (nodes) and changing land use.

The following section will examine each of the spatial dimensions on (1) how they are found, (2) what/how they contribute to the properties of complex adaptive systems, (3) what they mean in a spatial context and (4) how they can generate resilience.

Table 6.1 Properties of complex adaptive systems translated into spatial dimensions [based on a combination of the works of: Johnson (2001), De Roo (2006), Miller and Page (2007), Miller (2010), www.resalliance.org, Phelan (1999), Merry (1995), Eoyang and Conway (1999), Homan (2005), Gladwell (2000)]

Properties of complex adaptive systems		Spatial dimensions
Adaptive capacity	Diversity	Mix of functions
	Flexibility	Mosaic in city and landscape
	Heterogeneity	
	Reconfiguring	Space for natural resources
	Balance	
	Learning/storing	
Adaptive mimicry	Reproduction	Create free space
Self organisation	Collective patterns	
Emergence		Networks, number and importance
Indirect collaboration		
Large number of individual elements	Quality and quantity of connections	
Interactions	Jumps	Starting points, focal points
	Jets patronising	
	Tipping points	
Undergo change and retain basic features		Change in land-use, functions, human activities

- The *mix of functions* is based on the 'diversity' property of adaptive capacity. A more diverse city or landscape contributes to a higher adaptive capacity of the system. In spatial terms this means that when several different functions, such as living, agriculture, nature, water or industry are combined within a certain space, the diversity will be larger. In general, this also leads to intensive use of space, because functions are combined in close vicinity. When functions are combined, the configuration, mix and layout of the area can be more easily adjusted when an external 'shock' occurs, in other words the resilience of the area increases;
- *Mosaic in the city and landscape* has been derived from the properties flexibility and heterogeneity, which, once enhanced, increase the adaptive capacity of systems. When a 'mosaic' of spaces exists in the landscape or in the city, temporary and rapid adjustments are possible. In contrast, when large areas consist of mono-dimensional spaces, such as wide and open agricultural landscapes or extensive urban sprawl, adjustments at the edges of these spaces are possible, but it is hard to change the entire space. The mosaic in the landscape may consist of spaces ranging from large to small-scale and everything in between. Examples are meadows, mid-size agricultural complexes, nature areas alongside rivers, forests including open spaces, etcetera. In the city a mosaic of spaces may consist of public space of different sizes, living areas in different densities, compact neighbourhoods of the same spatial typology, parks of different sizes and so on. When it is necessary to change the spatial layout due to

an external factor, a differentiated spatial area offers much more opportunities for adjustment than a large space of a single type, hence the resilience of a differentiated area is higher;

- The *space for natural resources* focuses on creating balance between the demand for and supply of water, food and energy resources. When this supply, combined with improved ways to store resources within the area, can be permanently reconfigured, demand can be met, even if there would be sudden changes in it. If climate changes and causes unexpected new circumstances, shifts between the supply of energy, food and water may be required, so when the landscape is capable of enabling these kinds of changes, the adaptive capacity is greater, hence the resilience is larger;
- The rationale behind the *creation of free space* is to increase the space for development and reproduction of collective patterns. When new patterns and functions can be developed without being hindered by existing occupying functions, processes of self-organisation and adaptive mimicry can freely take place. Spatially, this means that parts of an area must be kept free of allocating specific land use. New collective patterns emerge in the city where no concrete function is foreseen. For instance, in many older cities, such as Amsterdam, Hamburg, Liverpool, London, Melbourne, to name a few, old harbour quays and docks became outdated and were not rezoned for a long period. During these periods of 'unuse' artists, small companies and new ways of living emerged, gentrifying and transforming those areas into hip and popular neighbourhoods. Eventually, these new collective patterns formed the basis for a structural redevelopment of the 'Docklands'. In this example, the 'free space' was available to accommodate new demands. When the future would demand extra space for flooding, sea level rise or energy supply, the availability of free space allows for these new demands to be accommodated. This potential increases the resilience of the area, compared with an area where new demands are impossible to fit in;
- The *number and importance of networks* is directly linked with the quality and quantity of connections. The networks of transport, water, energy and communication are taken into account. When there are more connections of better quality (faster, higher connectedness, more links, more intense) indirect collaboration between existing elements in the network/in the area will facilitate emergent patterns and functionalities. This type of highly connected networks keeps on functioning in uncertain circumstances and when unprecedented (weather) events occur. When required, these intense networks will develop emergent structures that start dealing with the event. By contrast, in single structured networks, without many connections, alternatives are difficultly developed. A good example of the latter is a neighbourhood located in the bush with only one road to and from the area. In case of a bushfire the access and evacuation to/from the neighbourhood is difficult and dangerous. It is obvious that a multiple connected neighbourhood has better chances to survive the event, hence represents a higher resilience;

- Within the networks crucial points, the *focal, or starting, points* are determined. These points form the most intense nodes, where networks are connected. Where a large number of network connections come together it is more likely that changes happen, new developments start and changes can be incorporated. Here, jumps or tipping points are most likely to occur, because the chance of interaction between elements is much larger than in less intense or not connected areas and nodes. Spatial examples of these nodes are crossroads, intersections, bridges, dams, river deltas, public squares, energy distribution hubs, communication hubs, airports, shopping centres etcetera. These nodes occupy the crucial and strategic places in the urban network and landscape. From here the rest of the area and networks are 'patronised', e.g. influenced and developed in a directive way. For instance, these nodes are the points where water is distributed in case of a flood, where the energy is distributed and exchanged in case of high or low demand or the places where the mode of transport is chosen and then occupied through the rest of the network. When these nodes can function as the 'tipping points' where developments can start when external 'shocks' occur, and redistribute the water, traffic or energy according to the available capacity in the network, these points contribute to an increased resilience in the area;
- A potential *change in land-use, functions and human activities* is fundamental in allowing change to happen. In many current spatial designs functions and activities are predetermined by the design and don't in allow the flexibility for changes to take place or, even stronger, to be stimulated. The property of a complex adaptive system to retain its basic features, whilst developing change, improves resilience. The adaptive system, in order to prevent itself from getting 'locked in', needs 'anticipating' tipping points to enhance change. The system needs to be triggered to change its land-use, human activities and functions, whenever external factors ask for it. For instance, if an area is flood prone the tipping point is defined as the moment at which the system 'breaks', e.g. is no longer capable of dealing with an overshoot of water. The anticipative tipping point already incorporates this in the precautionary changes the system undergoes. In other words, changed land-use, functions and activities are already in place, even before the external pressure on the system becomes too large. In this way, incorporated resilience becomes part of the system at a very early stage.

These spatial dimensions need to be seen as mutually complementary and form an integrated part of each particular area. Each of the dimensions is strongly related to the other ones and when used in a planning process can never be looked at from a separated perspective.

The other major aspect to discuss is the time factor. The pace at which a weather event occurs determines the way these spatial dimensions are capable of dealing with such an external 'shock'. If the hazard occurs suddenly, rapidly and by surprise, a resilient system already functions in a way that it can take up the impacts of the event. Given the fact that many weather events are unprecedented it is even more important to prepare ahead and have system properties in place that are anticipative.

6.5 Swarm Planning

When the spatially translated properties of complex adaptive systems are used in spatial design a new design paradigm emerges, which increases the resilience of areas, allowing the spatial system to jump to higher levels of complexity when necessary. This design paradigm is called Swarm Planning (Roggema 2005, 2008a, b, 2009; Roggema and Van den Dobbelsteen 2007, 2008; Roggema w. De Plaa 2009) Swarm Planning of those areas, i.e., spatial systems with increased adaptive capacity and resilience, requires three activities:

1. Increase the collective capacity to manage resilience (Walker et al., 2004). This requires a collective *future view* on what a resilient equilibrium, under threat of climate change and hazards, looks like. In this step the simple rules are defined that govern the behaviour of the swarm;
2. Define the *spatial elements*, as described in the previous paragraph, to be able to use the properties of complex adaptive systems in design and spatial processes. In this step the design parameters to work with (or the spatial elements the swarm consists of) are defined;
3. Start the process of increasing resilience. The jump to a higher level of resilience or complexity often requires an impulse. In this step the *crucial intervention*, which will start developments is defined. The swarm (the collective of spatial elements) responds to, prepares for or anticipates external changes and reshapes accordingly.

Swarm planning, implemented following these three steps is capable of increasing the adaptive capacity and resilience in spatial systems, and improving the capacity of regions and areas to anticipate (extreme) climate events. Swarm Planning is experimentally applied to design for floods in the Eemsdelta case study.

6.6 Swarm Planning Example: Floodable Landscape

In the current discourse about coastal defences for sea level rise and storm surges, the safety level is increased through the strengthening and heightening of protecting structures, such as levees and dikes. Fast and accelerated sea level rise as predicted by Hansen and others (Hansen 2007; Hansen et al. 2007, 2008; Hamilton and Kaiser 2009; Lenton et al. 2008; Rahmstorf et al. 2007; Tin 2008) raise concern about the capability of defences to withstand extreme circumstances at all times. Eventually, even the strongest dike will breach. The consequence of this belief in defending assets with an increasingly stronger dike is that once it breaches the impact is enormous, since the value of these assets is very high. A huge disaster will destroy assets of high value, such as properties, productive land and human life.

The Eemsdelta area is located in the North Eastern part of the Netherlands. The topography of the area is not very dramatic, but shows slight differences between the southern and northern parts. Surprisingly, the areas closer to the sea are around 1.5 m higher than the inland parts. The majority of the area is in agricultural use and most of the villages have historical value. The area faces the sea to the North and a large river, the Eems, to the East. This location makes the area vulnerable to the impacts of sea level rise. The coastal defence is formed by a strong dike, which has its weakest point at the eastern boundary of the case study area. Should the dike breach here the flooding would reach the major city, Groningen, within 36 h. Moreover, the area is the main supplier of natural gas, the extraction of which is under threat when such a flood would occur. Major economic development takes place in and near the Eems harbour, where energy supply, innovative and sustainable industries and main energy networks form a major asset. The area is one of the special attention and development areas for the regional government and one of the so-called hotspots for a climate adaptive spatial development. Planning for the area is under way and focuses on economic development, conservation of heritage sites and a sustainable and climate proof future.

Sea level rise in combination with storm surge, as the major threats from a climate change perspective, are taken as the starting point for the pilot-design. Given the uncertain pace of sea level rise and the specific moment the dike eventually will breach, it is worth exploring whether alternative designs may potentially be better equipped for decreasing the risk. The three stages of Swarm Planning, as outlined above, are used to increase preparedness and to anticipate future changes.

Firstly, a collective view has been developed. This view emphasises that: under accelerated sea level rise, even the strongest dike will eventually breach and alternative coastal defence solutions need to be investigated. The key drivers for this alternative are (1) water will flow to the lowest points, topography determines where those are, (2) sea level rise determines the level of the water and (3) a north western storm surge determines the moment sea water will eventually flow behind the defence.

Secondly, once this alternative view has been conceived, a design strategy was developed. This strategy, represented in Fig. 6.1, was based on the spatial dimensions of complex adaptive systems, as demonstrated previously. Core idea in the design strategy is to move along with expected change rather than fighting and withstanding it. Water is allowed to enter the hinterland from the beginning, giving people, institutions and all functions the chance to anticipate the future by acting as if this future is already real. This was done by creating an inlet at the most vulnerable point in the coastal defence and allowing water to inundate at a slow pace. Only when the sea level rises with respectively 0.3, 0.6, 0.9 and 1.2 m, a larger area will be impacted by intruding seawater. The urban developments are directed by this expected change over time. Houses and other functions are adjusted to these future circumstances, e.g. are built floating, amphibious or waterproof. Resilience of the area is increased through the following design interventions:

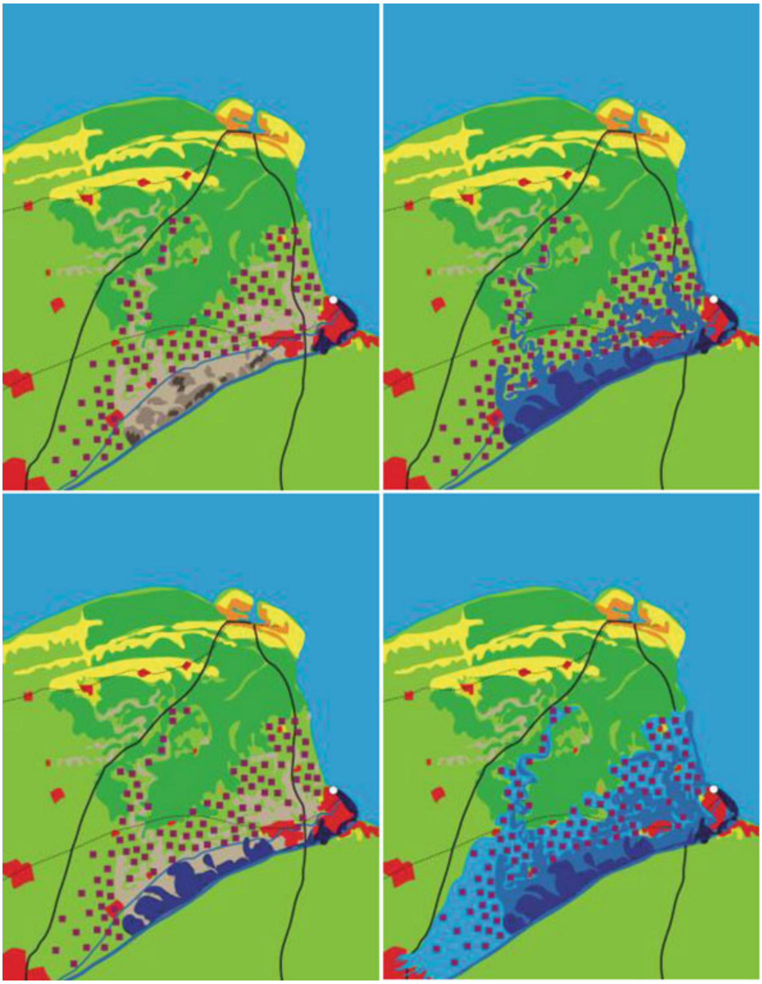

Fig. 6.1 Swarm planning for a floodable landscape at 0.3, 0.6, 0.9 and 1.2 m sea level rise (Roggema 2009)

1. The functional mix in the design is extended through the combination of new forms of living and building, natural water-rich areas and new forms of infrastructure, which are combined with the existing agriculture and cultural heritage landscape. The richness of the functional intensities allow for the configuration, mix and layout of the area to be adjusted more easily when an external ‘shock’ occurs hence increasing the resilience of the area;
2. The mosaic in the landscape is enriched through the introduction of temporary spaces, which are prepared for flooding, but in normal circumstances function as agricultural open spaces, natural wetlands or juvenile brook-forests.

This differentiated spatial area offers more opportunities to adjust it to unforeseen external factors;

3. Space for natural resources, such as water, food and energy is provided and these resources are stored in the potentially flooded area. The temporary character of the design allows for permanent reconfiguration of the supply. Demand can be met, even if sudden changes occur. When climate change causes unexpected new circumstances, shifts between the supply of energy, food and water may be required, so when the landscape is capable of enabling these kinds of changes, resilience is improved;
4. The design accommodates for free space for expected but undetermined 'extra' flooding, sea level rise or energy supply. This increases the resilience of the area when compared to an area where new demands are impossible to fit in;
5. The crucial focal point in the network in this area is the location of the weak point in the coastal defence. The design determines this node in the network and defines it as a tipping point for change. From this node development start to emerge, forming new patterns of where the water may flow, meanwhile determining new qualities of living, water management and nature;
6. This node, the first place where pressure on the system will enforce change can be seen as the 'anticipating' tipping point for change. Here, the system is triggered to change its land-use, human activities and functions, because the external pressure asks for it. The landscape is prepared for receiving water and the buildings are prepared for water in their environments. In other words, the changes in land-use, functions and activities are already in place, even before the external pressure on the system becomes too large. In this way, incorporated resilience becomes part of the system at a very early stage.

Finally, as the third phase of Swarm Planning, the process of resilience starts: instead of keeping strengthening the coastal defences, the design proposes to create a hole in the dike in an early stage. This will start the process of adaptation to future circumstances, even when it is not known what those will be exactly. This hole in the dike leads to a slow transformation of the area, 'hosting' more water as sea level is rising.

An advantage of this design approach is that it prevents damaging impacts of a large disaster, because the water has already been allowed to enter the hinterland and is treated as an ally rather than as an enemy. Because it is possible to accurately predict where the water will flow, people, buildings and organisations are capable of adapting in an early stage. The water will bring gradual changes and benefits. At first, brackish conditions will emerge in the unplanned areas, allowing enrichment of ecological conditions. Secondly and in a later stage all new buildings face water in their environment, a real estate asset of great value. The biggest advantage will probably be the fact that due to the slow pace of entering seawater a disaster never actually happens, but it is tamed to a gradually changing wet environment, which makes the area inherently safe.

Despite the fact that this chapter does not focus on political or community processes, which facilitate the realisation of spatial design, a design, and especially an innovative one, is worthless without support from decision makers and citizens. In this specific case study the iconic image of a landscape that disappears under water makes the role of politicians and the community even more important.

The political context in this area is complex, but driven by urgency. The fact that several municipalities, a province and two water-boards, all being democratically chosen, govern the area makes decision making complex. However, the fact that climate change may have huge impacts and economically valuable assets, such as the National gas extraction fields and the harbours, are at stake, combined with the fact that the population in this area is shrinking, gives politics every reason to be interested. This was the reason that the regional government, in collaboration with the other responsible governments, developed a structure vision for the area in which climate adaptation plays an important role. There was also awareness amongst responsible mayors, councillors and regional ministers that innovative ideas are essential to find a strategy to increase resilience. The somewhat out-of-the-box design proposals were welcomed as valuable suggestions, but were not immediately embraced as the one-and-only overarching solution.

The community, despite the fact that population is shrinking and inhabitation densities are fairly low, was involved in the design process. The design ideas were shared in an early stage and were communicated carefully. The fact that the proposed strategy could prevent an unexpected disaster with large impact created support. Two elements were crucial in gaining support amongst communities. The first element is time. The pace of proposed changes is slow, which allows individuals to adjust step-by-step and determine their moment of leaving the area or to stay and accept changes. These kinds of decisions are not easily made and require time. The pace of change will be so slow that it matches the decision making process. The second factor of importance was the potential increase in property value. The new landscape is a landscape in which water plays a dominant role and existing houses are repositioned in the midst of a water-rich environment and in the middle of nature. These are assets that increase average real estate value. Only farmers voiced a negative reflection on the ideas. They faced the choice of either leaving their generation-long owned land or adjusting crops and farming techniques to the new, more saline circumstances.

6.7 Conclusion and Discussion

As discussed in this chapter climate adaptation faces uncertainty because changes in climate are difficult to predict. This causes a dilemma in a spatial planning and design context, because failure to include adaptation in spatial plans may lead to *non-adaptation,* which leads to a bad or no preparation for future changes. On the other hand, taking action now incorporates the risk of *mal-adaptation*, making wrong choices and preparing society in a bad way for the future. The cause of this lies in the complex character of uncertain and long-term climate adaptation, while spatial planning and design is oriented on the relatively short-term and consists of pretty straightforward (tame) activities.

This chapter has described a potential way out of this dilemma, namely through the usage of properties well known in complex adaptive systems theory to describe spatial systems. However, complex adaptive systems are studied in a limited number of fields, such as ecology, sociology, computation and organisational theory. Therefore it is necessary to translate the properties of complex adaptive systems to spatially relevant entities, such as typologies, numbers and amounts of these entities, in order to use them to design regions that are more resilient and have a larger adaptive capacity. The chapter demonstrates the possible use of these entities in spatial planning and design practice and to our knowledge this is the first attempt to achieve this. The spatial characteristics, derived from these properties form the second step of the Swarm Planning methodology, which consists furthermore of the first, development of a collective view, and the third step, start the ignition and emergence of the increase of resilience.

The case study shows how this methodology can be used in the development of a spatial design and how the complex adaptive entities can be applied. The results of the case study emphasise that resilience can be enhanced when these properties are used to conceive the design, but the case study does not 'proof' an improved resilience, hence this requires further elaboration. The results of the case study need to be quantified and compared with other case studies, which need to be developed.

Finally, when spatial systems are seen as complex adaptive systems, which behave like swarms, the resilience and adaptive capacity of regions can be increased. However, endless trust in *engineering* spatial solutions withstands widespread implementation of these principles in practice. Continuing on this pathway of engineering our way out of problems the solutions may appear robust, but lack resilience and, in dealing with extreme weather events, this will lead to more disasters. In the alternative design that incorporates potential effects of severe weather events in designs and the spatial layout of an area as demonstrated in this chapter, future hazards are no longer a surprise, but will have become part of the 'existing': the area has already adapted before it is confronted with disasters.

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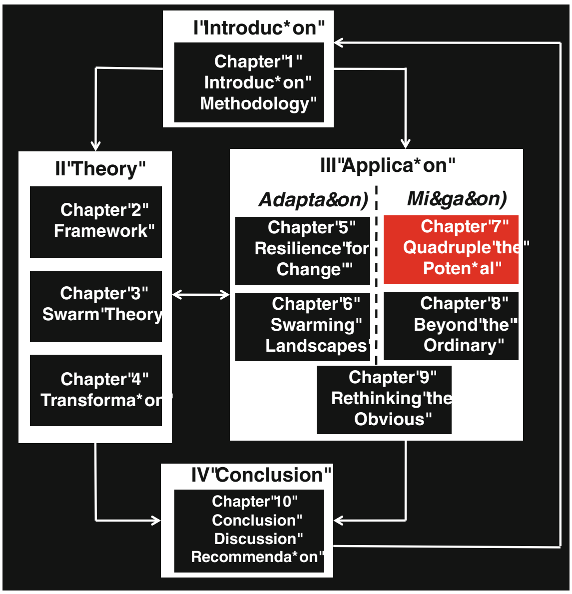
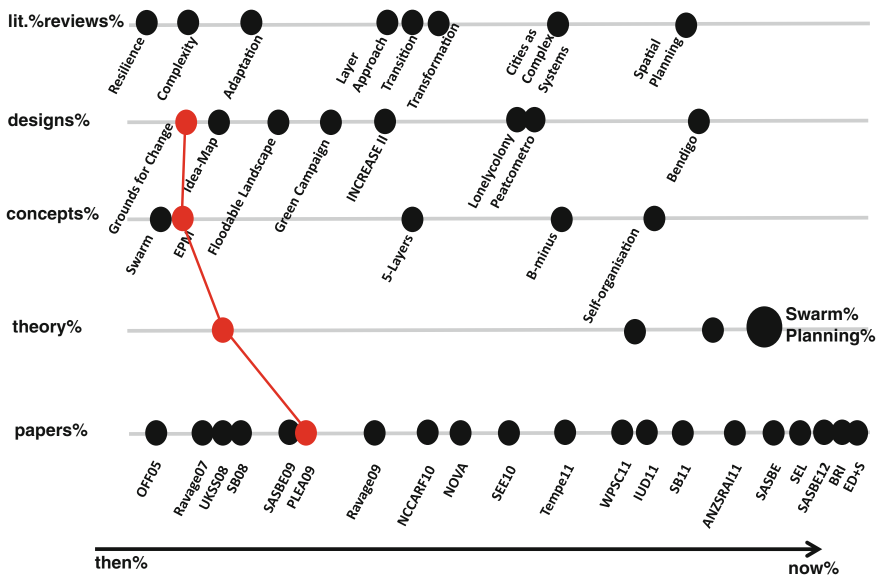
The Bridge: Six–Seven



Chapters 5 and 6 mainly focused on the application of the Swarm Planning Framework for climate adaptation. Chapters 7 and 8 applied the framework to design landscapes for climate mitigation or, the arrangement of landscapes that harvest enough sustainable energy. Chapter 7 is elaborating the availability and local potentials of possible renewable energy resources as the basic informant of spatial design. Four separated spatial scales are distinguished, each with their own characteristics. For each scale renewable energy potentials need to be discovered, mapped, used in the design and calculated. This methodology, Energy Potential Mapping (and Design) emphasises that current policy aims are, compared with local and regional potentials, not extremely ambitious. For nearly every spatial scale a surplus of energy can be harvested using renewable resources. This article/chapter is published in the proceedings of the Passive Low-Energy Architecture (PLEA) conference, 2009.



Chapter 7
Quadruple the Potential, Scaling the Energy Supply

7.1 Introduction

The dependency on fossil fuels and the fact that oil, coal and gas are world markets and the rules within these markets dictate what is possible, desirable and realistic, prevent a real transition towards a sustainable energy supply from happening.

The traditional approach aims to make the existing system a little bit more sustainable. But still, world market rules define the framework within which the pace of changes is permitted to take place. This way of thinking generally leads to difficult reached agreements on ambitions. The 2020 objectives of the EU (Commission of the European Communities 2008) for example, are to reduce greenhouse gas emissions and increase energy efficiency both by 20 % and aim to increase the proportion of renewable energy to 20 %. The Dutch government formulates its goals alike: save energy by 20 % and reduce greenhouse gas emissions by 30 % in 2020 (CDA et al. 2007). These ambitions do not seem enough if the IPCC is to be believed. The IPCC has concluded that CO_2 emissions should be reduced by 50–85 % in 2050 in order to stabilise global warming between 2 and 2.4 °C (IPCC 2007). The IEA states that a global revolution is necessary in the ways that energy is supplied and used (IEA 2008). Current pathways and transition paths seem not fast and ambitious enough.

However, the transition can be looked at from the opposite direction. If the availability or regional potential for sustainable energy in a certain region decides on the ambitions and the way energy is produced and supplied and not that global market rules dictate the available space for the use of sustainable energy, the usage of local and regional potentials will increase. The transformation of the energy supply into a renewable energy system, based on the local production of available renewables and a distribution system, which is based on the recent opportunities of

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R. Roggema, *Swarm Planning*, Springer Theses, DOI: 10.1007/978-94-007-7152-9_7,

communication technology, energy-web, is a new era in energy supply is apparent (Droege 2006; Rifkin 2002).

So far, few studies with the objective to find out how local sustainable potentials can be used are conducted (Van den Dobbelsteen et al. 2007, 2008; Droege 2006; Roggema et al. 2006). These studies make visible by using maps where the potentials for different sustainable energy sources can be found.

When these studies are combined a system can be created, which functions like the famous Droste effect: findings regarding the potentials for sustainable energy supply on the supra-regional scale determines what the potentials are on the regional scale, which determines what the potentials are on the local scale, which consequently determines what the potentials are on the building scale. Combining the potentials at all scales will result in far higher ambitions than the current policies define.

The most important constraints include the existing cultural setting of decision-making, the ostensible dependency on large energy companies, the addiction to the existing power relations of important meets important, the seemingly immovable trust in existing infrastructure. Every scale has its own possible contribution and characteristic.

7.2 The Supra-Regional Scale: North Netherlands

On supra-regional scale the combination of a very energy efficient supply system with the regional layout determines the potentials (Itoh 2003). Therefore, it is important to create the basis of knowledge: to gain insight on where the different potentials are highest and what a combined energy typology implies (Roggema et al. 2006). On the supra-regional scale of Northern Netherlands the energy potentials for wind, solar, geothermal, biomass and hydro are mapped (Fig. 7.1).

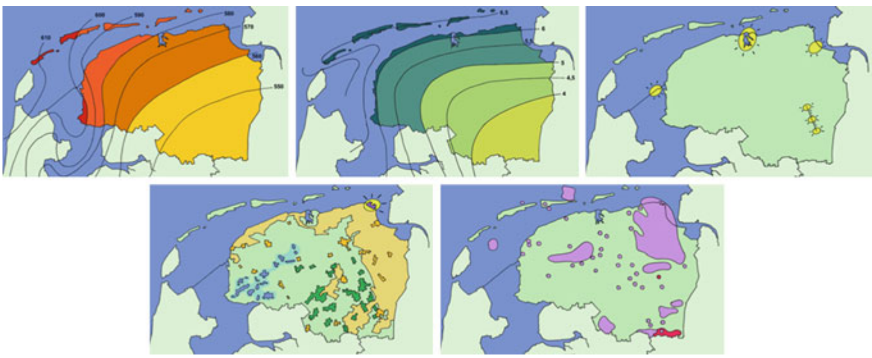

Fig. 7.1 Regional energy potentials in Northern Netherlands: solar, wind, hydro, biomass and geothermal (Roggema et al. 2006)

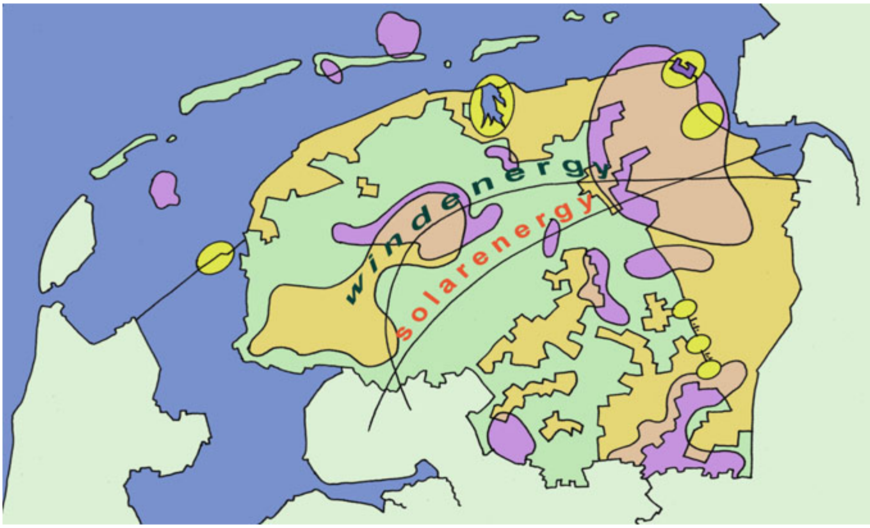

Fig. 7.2 The energy-mix map, showing for each location the optimal mix of energy potentials (Roggema et al. 2006)

If these potential maps are combined the so-called energy-mix map is constructed (Fig. 7.2).

This map shows spatial energy typologies: for every sub-region it becomes visible which combination of sustainable energy resources is available. The map does not give a directive for land use. Any function can be located anywhere and can make use of the available resources.

The benefit of the energy potential mapping at the supra-regional scale is that every sub-region knows its specific and most optimal combination of energy resources, which can be used for a planned or an existing function. Making use of this energy potential instead of imported gas or oil reduces the use of fossil energy. The main aim at the supra-regional scale is to identify the available mix of sustainable energy potentials in the region.

7.3 The Regional Scale: Groningen

The aim on the regional level is to determine the best location for functions from a sustainable energy point of view. For that purpose, the energy potentials are mapped and combined with the *low-ex* principle on the provincial scale (Van den Dobbelsteen et al. 2007).

According to the 1st Law of Thermodynamics, energy is never lost, but the 2nd Law describes the increase of entropy, implying the decrease of something else. This is energy. By definition, energy is the maximum work potential of matter or energy in relation to its environment. It can be considered the high-quality part of energy (Shukuya 2004). The low-energy principle encompasses reduction of energy losses in and between processes, the use of high-quality energy for high-graded functions only and the utilisation of waste energy flows from these by lower-graded functions. The low-ex principle assumes cascading of energy qualities, and in a spatial context the mixing and energetic inter-connection of spatial functions such as industries, horticulture, offices and dwellings (IEA Annex 49 2007).

In the province of Groningen the potentials for wind, solar, geothermal, biomass, hydro and the use of rest-heat from buildings and industry are mapped as a result of the existing situation (topography, existing energy system, climate, etc.) and translated into maps that show the potentials for fuel, electricity, heat and cold and CO_2 capture.

The map for heat and cold (Fig. 7.3) shows that the largest combined potentials are found near the northern parts of the province, around the Eems harbour (rest-heat) and the Lauwers Lake (geothermal heat). The electricity potential map (Fig. 7.3) shows that two zones are interesting: the coastal zone (wind and hydro) and the central highway zone (central location for biomass processing).

If all sustainable energy and energy potentials are combined a provincial energy-mix map can be derived (Fig. 7.4). This map forms the foundation for decisions about the most optimal positioning of specific functions.

The energy-mix map shows indications on the most optimal locations for functions or combination of functions. The functions are able to use sustainable resources there or use energy more efficiently.

These potentials can be translated into spatial interventions (Fig. 7.5).

The map shows the proposed functions: new living neighbourhoods where geothermal heat is available (near Lauwers Lake), living neighbourhoods and greenhouses where rest-heat can be used (around Eems harbour and Delfzijl) and the different locations for electricity plants (wind, biomass, tidal, osmosis, inundation). These spatial interventions are based on energy potentials. Spatial planning can be directed by spatial knowledge about the availability of sustainable energy resources. The best or most efficient locations can be chosen for urban as well as agricultural functions.

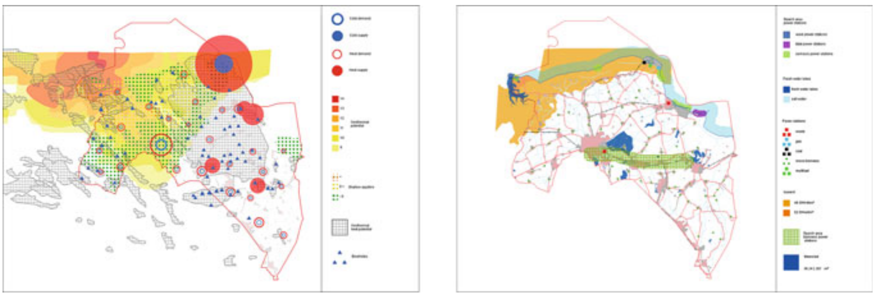

Fig. 7.3 The potentials for heat and cold (*left*) and electricity (*right*) in the province of Groningen (Van den Dobbelsteen et al. 2007)

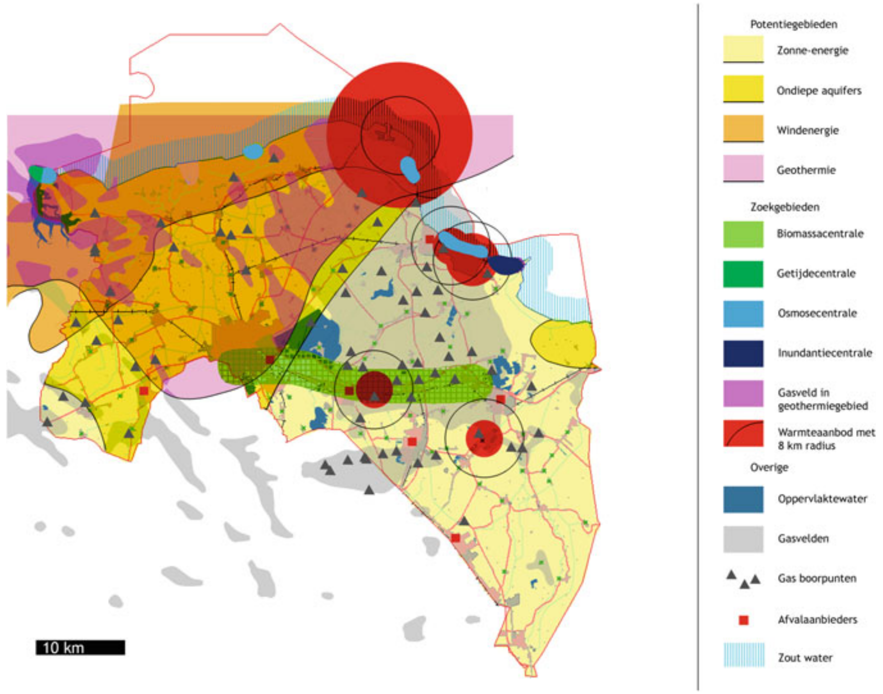

Fig. 7.4 Map of Groningen with the mix of energy potentials (Van der Grinten 2008)

The benefits of these spatial interventions are calculated. If all spatial measures are taken 50 % of the current energy demand is serviced, which is four times current percentage of the use of sustainable resources in the Netherlands. Besides this, a reduction of 80 % CO_2 emission reduction is reached, which is four times the current objectives in EU and the Netherlands.

7.4 The City-Neighbourhood Scale: Almere East and Hoogezand

At the local level of a city department or neighbourhood the potentials no longer determine where a certain function can be positioned best, but they influence the lay out of the settlement, city or neighbourhood. These potentials are mapped and give insights on the organisation of the functions in the urban pattern. Beside the usage of sustainable energy resources, on this scale the exchange of energy via the grid can be taken into account. The research projects of Almere (Van den Dobbelsteen et al. 2008) and *The Green Campaign* in Hoogezand (Van den Dobbelsteen et al. 2009) illustrate this.

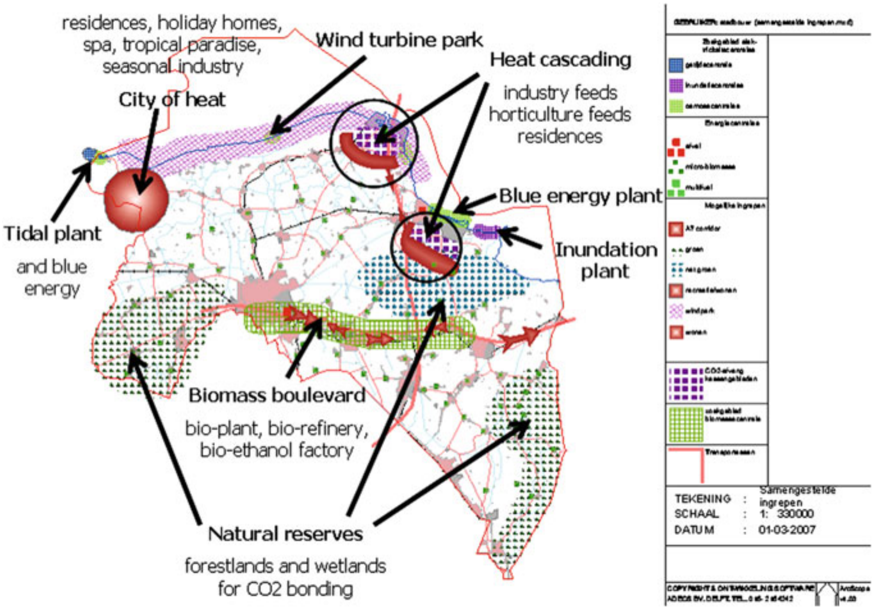

Fig. 7.5 Map with the spatial interventions based on energy potentials (Van den Dobbelsteen et al. 2007)

7.4.1 Almere East

The Dutch city of Almere, near Amsterdam, wants to double in size within the next 15 years and develops extension plans for this. The Delft University of Technology was asked to conduct an energy potential study of the new districts of Almere. Almere East (approximately 4,000 ha) was one of these. Here specific local potentials were related to the agricultural hinterland, which it is now, as well as good opportunities for wind and sun (Fig. 7.6).

On the basis of the energy potential maps for Almere East, spatial design interventions were suggested. Figure 7.7 and 7.8 depict the two main variants proposed. Interesting feature of the first is the deployment of existing agricultural enterprises in the plan, forming the cores of energetically self-sufficient clusters of a farm with 30 dwellings. Greater quantities of housing developments can be combined with offices and light industry in the north of the district, which is the only place where heat and cold can be stored in open aquifer systems.

The second variant (Fig. 7.8) was more strongly based on a grid-connected strip of high-density building along the motorway, simultaneously acting as an acoustic barrier, so that the inner location behind it can be developed in various yet all energy-neutral ways. The high-density building strip is connected to a grid of heat, cold and power, using waste energy flows from the different functions, including the power plant nearby.

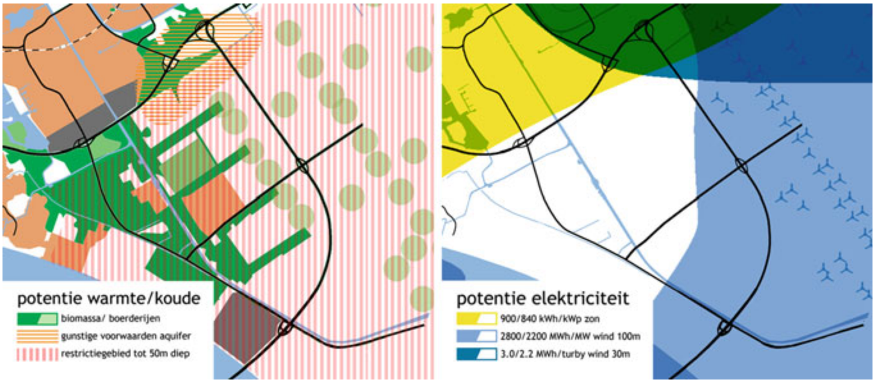

Fig. 7.6 Potentials for heat and cold (*left*) and electricity (*right*) in Almere East (Van den Dobbelsteen et al. 2008)

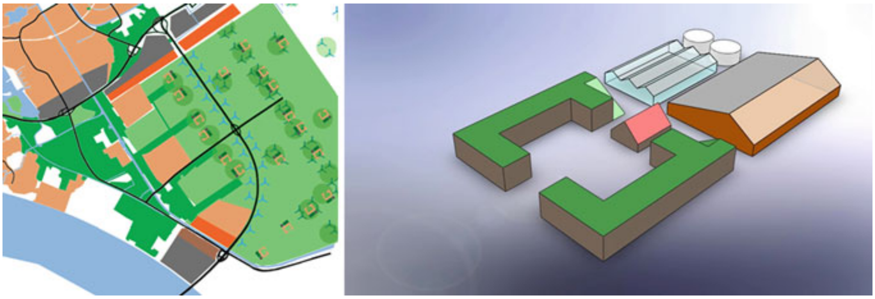

Fig. 7.7 First variant for Almere East (Van den Dobbelsteen et al. 2008)

Fig. 7.8 Second variant for Almere East (Van den Dobbelsteen et al. 2008)

The proposals based on energy potentials deviated considerably from plans already drawn by the urban designer. After presentation the municipality of Almere studied the possibility of adjusting the existing plans to a more energy-effective one.

7.4.2 Hoogezand: The Green Campaign

On a smaller scale than Almere East, the town of Hoogezand-Sappemeer intends to develop a new site for living south of the present built-up area, called The Green Campaign. Similar to Almere East is the current agricultural character. The Green Campaign however has features that make it different from the other location.

There are many limitations regarding noise and odour nuisance zones, high-voltage lines and historic (untouchable) lanes. Nevertheless, there are interesting potentials, for instance, a few 'hotspots' of a specific energy potential: a chicken farm (chicken manure for co-generation of heat and cold), a cardboard factory (waste heat) and a gas drilling station (geothermal heat from 3 km of depth).

Research is ongoing. At the moment of writing three fundamental concepts are elaborated on: one based on interconnections with existing hotspots of energy, one based on self-sufficient neighbourhoods (with decentralised technical utilities) and one with independent autarkic dwellings.

7.4.3 Experiences with Energy Potential Studies

Energy potentials can influence the layout of neighbourhoods. If the energy-mix is known at the supra-regional level and if functions are located at the right positions on the regional level, the layout of the city district or neighbourhood can be done accordingly. The use of available potentials can play a directive role in the design for the urban patterns. If, on top of that the exchange between the use as well as delivery of energy to and from the grid is made possible the results can be improved even more.

7.5 The Building Scale: River House Mildura

At the building level the River House Mildura (Fig. 7.9) exemplifies how local potentials can be used for the design (Saman et al. 2008; Sustainable Energy Authority Victoria 2002). The use of local potentials like the need for heat and cold, shadow, the sun, ventilation and wind, shelter and material use, once they are mapped, are integrated in the design. If the sources and circumstances are integrated a net positive energy production is possible, thus deliverance to the grid.

Fig. 7.9 Mildura residence—north/east elevation facing the Murray River

Resources were defined on the site, and their potentials exploited.

- Mapping of the semiarid climatic conditions enabled the design to capture and work with free potential resources.
- Local materials were integrated into the thermal mass earth walls.
- Mapping of the site and adjoining land revealed shading opportunities and informed the designs landscape design response.
- Analysis of sightlines informed a more specific and sophisticated response to capturing views.
- Re-viewing the brief and mapping the amenity requirements of the client discovered resource savings in terms of reduced built area.

Mapping the functional requirements (Fig. 7.10) of the client (resources) enables a design evolution that reduces the overall area of building. In this case the second level was consolidated and the inserted into the ground level footprint.

Mapping the solar path (Fig. 7.11) provides an understanding of the spatial relationship between the site and design options.

The resource of sun requires seasonal control, the design utilises the existing trees to protect from the low morning summer sun. The architecture integrated a subterranean air labyrinth utilising the lower soil temperatures to provide cooling

Fig. 7.10 Functional mapping

Fig. 7.11 Winter sun (*left*) and summer sun (*right*) analysis

during summer. Passive systems provide a greater level of comfort than predicted by the simulated model. The simulation indicated that the living spaces would fluctuate by up to 7.5° and the monitored results were closer to 5°.

If the actual versus simulated results by Energy Plus are compared, the actual results outperform the simulated. In near zero conditions the building requires negligible heating to maintain a comfortable internal temperature. Energy Plus predicted a much higher heating demand under less severe outdoor temperatures (Table 7.1).

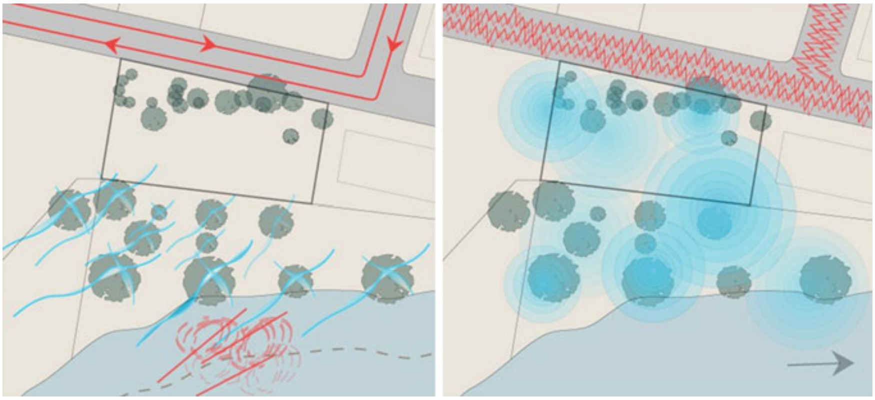

Fig. 7.12 Movement analysis—the poetic resource of nature to be captured (*left*) and Noise analysis—the chaotic sound of traffic to be controlled, whilst capturing fauna sounds (*right*)

Table 7.1 Heating and cooling comparison between Mildura River House and average home

	Gas heating and electric cooling (%)	Electric heating and cooling (RCAC) (%)
Energy saving (% saved)*	64.0	64.0
Energy use of renewables (as % total use)+	33.0	33.0
CO_2 emissions (% less than normal)	73.0	84.6

* This figure includes lighting
\+ This figure excludes the renewable component of the passive climatic systems

7.5.1 Potentials and Outcomes

The success of resource mapping is apparent in this development. The aim was to reduce the energy consumption with 50 % over a similar home in a comparable area and exceeded this. This, and even a higher ambition of 64 %, was achieved by overlaying the responses to our resource mapping. These included mapping the sun's path (Fig. 7.11), the sight lines, the subterranean temperature (used in the development of the labyrinth), materials and other potentials (Fig. 7.12). The intended gains from every single system were improved upon when it operated in conjunction with another system. Monitoring revealed by the actual data logging of the property exceeded the simulated model's predicted performance. The interaction between the passive and active systems offers greater gains through the complexity with which each system operates. By responding, finding windows of opportunity and ultimately producing an organic system that works reciprocally within other systems to produce an elastic loop, these gains were reached.

7.6 Interdependencies

If energy potential mapping is carried out at several spatial scales lower scales can profit from the knowledge about the availability of sustainable resources at higher levels. At the lower scale better choices can be made on the lay out and order of functions in order to increase the use of sustainable resources. The big win is that if is known what the available sustainable resources at the higher scale are, it can be determined what the useful resources are at lower scales. This way of thinking is not yet practiced and large improvements can be made.

If reaching energy saving or emission reduction objectives are discussed so far, the building is seen as the relevant subject. This leads logically to making the house/building as efficient as possible: energy saving and the provision of sustainable energy as much as possible. If the building is seen as interdependent with higher scales, the positioning and the design of the building in the chain of spatial scales make more ambitious objectives possible.

There are several interdependencies between the different scales (Table 7.2). The characteristics at the highest level mark the possibilities on the regional scale. Once the potentials are known on the regional level the most optimal functional zoning, including the available sustainable resources, can be proposed. At the regional level the principle of energy is added. If the location for a certain function is known, the spatial design of the urban patterns can be undertaken, making use of the available resources. At the local level the exchange with the grid is added in the process. And once the lay out of the area is chosen the available resources to be used in the design of buildings. At the building level elements such as comfort and beauty are added.

It is possible, with incorporation the higher levels of scale in the energy supply chain to reach much higher levels of use of sustainable energy and reduction of green house gas emissions than current policies aim can be reached. The examples in this paper illustrate that result up to four times higher can be reached. This means that policy objectives can be quadrupled easily.

Table 7.2 The role and benefits of different scales

Scale	Role	Results
Supra-regional	Which potentials are where	Not relevant
Regional	Which pattern of functions is best Potentials + energy	Sustainable energy use: 50 % CO_2-emission reduction: 80 %
Local	How need the lay out of the function be Potentials, energy + exchange with grid	Energy and CO_2 neutrality or even energy surplus
Building	What is the best design Potentials, energy, grid and comfort	Sustainable energy used: 33 % Energy saving: 64 % CO_2-emission reduction: 73–84.6 %

7.7 Discussion

The results in the different studies show that far higher objectives can be reached than in current policies are written down. The added gains at every spatial level offer a quadruple effect. If an energy efficient house is built certain saving objectives are reached. If the same house is built in a sustainable energy directed urban pattern these houses profit from the right circumstances. And if the neighbourhood is planned at the right place in the region and making use of the available resources the results show that the potentials can be quadrupled.

Major constraints to implement the method are the existing power balances between decision-makers. As long as large energy companies remain power over infrastructure their dominance over the decisions on used resources cannot be changed. The hidden agreement between governments and energy companies about a mutual dependency on global market rules and the fact that it is impossible to change anything about is leading to the continuation of the existing system. Finally, it is far easier for people to decide on what they are used to instead of decide for a breakthrough or an innovation. This makes it hard to start the process of thinking from the other side than the usual and prevents us from reaching quadruple results.

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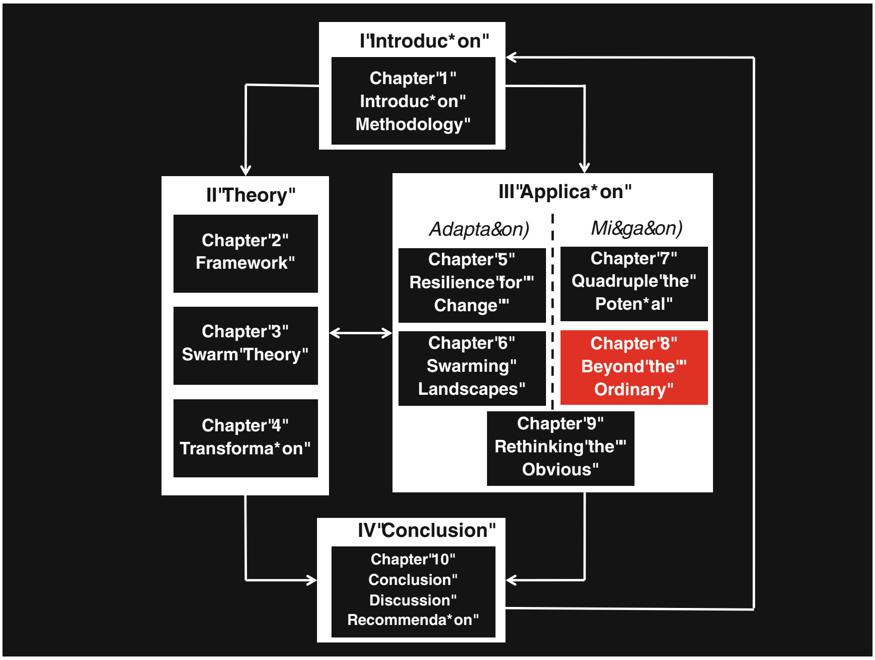
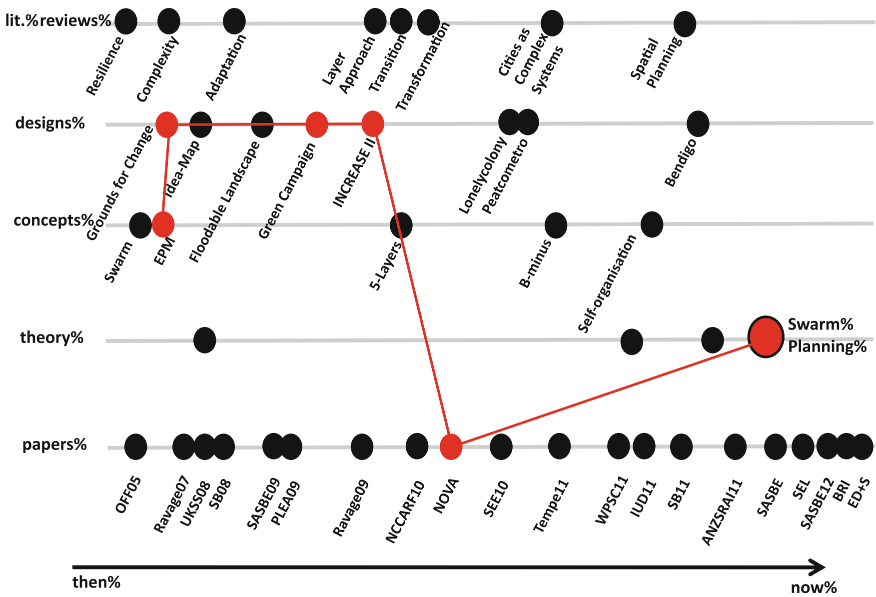
The Bridge: Seven–Eight



Chapter Seven emphasised the potential to harvest renewable energy resources to provide energy at different spatial scales and how this data informs spatial designs at the different scales. In chapter eight this methodology is connected with the Swarm Planning Framework. In three steps the design of a Climate resilient design is conducted. In the first step, local and regional renewable energy potentials are mapped and located. Secondly, this information is used to conceive a regional design. The final step is the way to realise the design ambitions. This is found in identifying the strategic locations where the transformation towards a sustainable energy supply can be initiated. These locations are found on the basis of a network analysis, in which not only the energy-grid is subject of research, but also the linkages with the water- and transport network are found important. Once these points are found they are used as the places where spatial interventions are placed. As a result of these interventions, the local environment starts to change and will evolve and transform in an adjusted system, which supplies energy in a more resilient way, for instance because it functions autonomous from external energy suppliers. This chapter/article is published as a book chapter in *Climate Change Adaptation: Ecology, Mitigation and Management*, 2011.



Chapter 8
Beyond the Ordinary: Innovative Spatial Energy Framework Offers Perspectives on Increased Energy and Carbon Objectives

8.1 Introduction

Since the discovery of oil and gas, energy has been abundant and inexpensive. However, Campbell and others demonstrated that oil production already peaked (Campbell and Laherrère 1998; Campbell 1999, 2002a, b; Kaufmann 2006) and that the end of the oil era is near (Rifkin 2002; Belin 2008). This culminates in fast rising oil prices, despite the fact that prediction is difficult. According to the *International Energy Outlook 2002,* until 2020 the oil prices would not exceed $40.[1] Three years later the *International Energy Outlook 2005* stated that in 2020 the maximum price for crude oil would be around $50.[2] And finally, the *International Energy Outlook 2007* predicted an $80 price for one barrel of crude oil in 2020.[3] The main problem here is not the inadequacy of the predictions for 2020, but the fact that by the beginning of 2008 one barrel of crude oil cost more than $140 and that it is not possible to find any prediction in 2007 that a barrel price would reach this amount in that year (Van den Dobbelsteen et al. 2009b). High oil prices imply higher living costs, such as the expenses for transport or the energy used in houses (Sergeev et al. 2009), yet also indirectly the price of any goods in the market.

Moreover, the way energy is supplied, converted and used is very inefficient (Stremke et al. 2011). The Sankey diagram (Fig. 8.1) illustrates that, on a global

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[1] *International Energy Outlook* 2002, p.26.
[2] *International Energy Outlook* 2005, p. 28.
[3] *International Energy Outlook* 2007, p. 30.

R. Roggema, *Swarm Planning*, Springer Theses, DOI: 10.1007/978-94-007-7152-9_8,

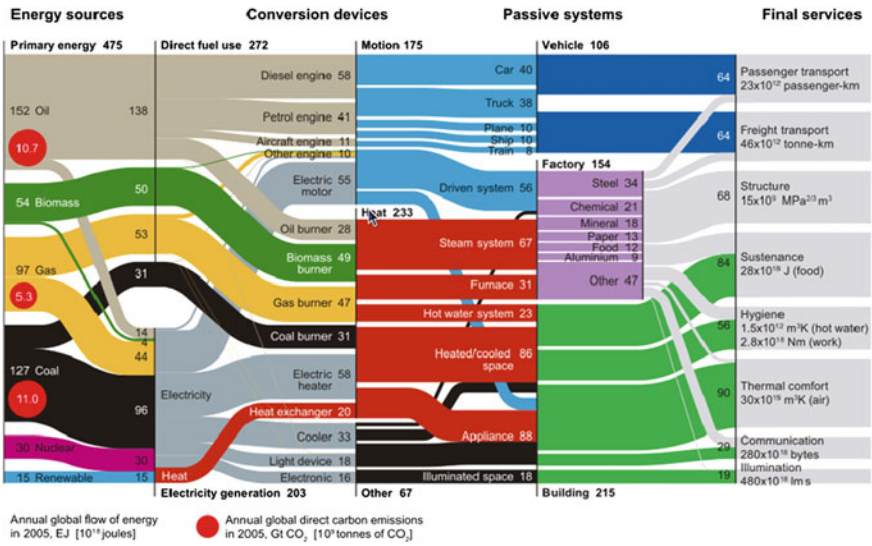


Fig. 8.1 55 EJ of useful energy is derived from 475 EJ energy sources: 11, 6 % [*Source* Cullen and Alwood 2010]

level, only 11.6 % of the energy sources is turned into useful energy (Cullen and Hall 2009; Cullen and Allwood 2010; Van den Dobbelsteen 2010).

Not only high prices of energy or the fact that burning fossil resources contributes to climate change motivate a transition towards sustainable energy supply. A structural change is also required because fossil resources[4] will be depleted in a period of less than 100 years (Hoogakker 2006). This is caused by the fact that running out of the first fossil resource subsequently leads to an accelerated depletion of the next. In the BP statistical review the R/P (Reserve to Production) ratio for coal, oil and natural gas is estimated 120, 45 and 60 years respectively (BP 2009), however, this does not take into account that when oil is finished, the depletion of gas and coal will be accelerated. Therefore, the longer term aim is to develop a society that functions without the use of fossil resources. Dril (2010) demonstrates that current policy will not enable to achieve this goal, because existing market powers object transition, implementation of change is too slow and policy cannot enforce a fundamental shift in energy supply. In addition, people seem not to be willing to pay for energy-efficient houses (Van Estrik 2009).

The question that can be raised is if a transition towards non-fossil will occur through incremental steps or through discontinuous processes of subsequent breakthroughs, the incremental approach mainly focuses on achieving what is already possible. A certain agreed target, such as to reduce CO_2 emissions by 20 % by the year 2020 (European Parliament Council 2009) or the energy agreement for

[4] Including finite yet non-fossil nuclear energy.

the Northern Netherlands (Samenwerkingsverband Noord-Nederland et al. 2007), determines the maximum achievable level. The transition model as described by De Roo illustrates this continuous process (De Roo 2008). There is no incentive to realise higher targets than the maximum aim; the aim even limits the realisation of a fundamental change towards a complete sustainable energy supply. Several studies (Van den Dobbelsteen et al. 2007a, b; Broersma et al. 2009) illustrate that an approach based on the available potentials of a certain area, enables realising much higher targets. However, these high ambitions are only attainable through the enforcement of breakthroughs, as illustrated by Perez (Perez 2002) or, as complexity theory explores, enforcing a jump to a higher level of complexity (Geldof 2001; Zuijderhoudt 2007; Peeters and Wetzels 1997). This process of subsequent and discontinuous phases and shifts, as described elsewhere (Roggema et al. 2012b), places the local energy potentials in a central position.

8.2 Problem

Fundamental change, such as the transition to a completely sustainable energy supply, is difficult to realise via a smooth transition pathway only, especially if circumstances are complex and turbulent. In such environments an incremental transition may lead to suboptimal results and the goal of transforming into a fully sustainable energy supply may not be timely reached.

8.3 Hypothesis

In order to achieve the potential target of a completely sustainable energy supply it is necessary to facilitate breakthroughs. These breakthroughs can be enforced through the implementation of discontinuous 'jumps'. Spatial planning is the field in which this can be implemented and the use of Swarm Planning principles (Roggema 2005, 2008a, b, 2009b; Roggema and Van den Dobbelsteen 2007, 2008; Roggema w. De Plaa 2009) increases the number of possibilities.

8.4 State of the Art in Renewable Energy Thinking

Current thinking in renewable energy reflects a technological-financial approach. There are several difficulties in transforming the present energy system towards a sustainable system:

- The first reason is that availability and feasibility still are central issues. The question often asked is whether a certain energy technique available and if this technique is already feasible. Often, the aim seems to be to realise a particular renewable energy technique. This focus implies a blinkered view on a specific technique and description of the pros and cons of them, as illustrated by many studies in which the different resources, such as solar, wind, hydropower, biomass and geothermal are considered separately (Van der Hoeven et al. 2009; MacKay 2009; Gemeente Groningen 2010). These techniques are realised only when feasible. This approach results in isolated and sectored interventions mainly taking into account one or few renewable energy resources. Realisation of the most feasible techniques will be prioritised and realised accordingly. This can be illustrated by the advice of the Innovation Platform in the Netherlands (Innovatieplatform 2010), implying that from a sustainability point of view not the most profitable yet the most feasible measures be realised first. This postpones the realisation of a sustainable energy supply. As long as a certain percentage of a particular renewable energy source is simply considered as a target instead of a means towards a sustainable energy supply, breakthroughs to a fundamentally changed system will be difficult to realise.
- Second, the energy companies do not invest in sustainable energy sufficiently to achieve the 20 % sustainable energy targets, while even much higher percentages are required to mitigate climate change. Research conducted by Persson (2010), which consisted of questionnaires amongst all energy companies active in the Netherlands, confirms that even if the most uncertain assumptions are taken into account, the 20 % target will not be reached in 2020.
- The third reason is the strong focus on the transition period rather than focussing on the final goal. Much effort is put in defining the role of natural gas as transition fuel towards a sustainable energy system (Rooijers et al. 2008; Bruin, 2010), for instance in the form of gas-fuelled combined heat and power (Bartolomeus and Overdiep 2005; Goudswaard et al. 2008), or mitigating the effects of coal-fired power plants through Carbon Capture and Storage (CCS) (Van Ansem et al. 2009). Most efforts and investments in the transition phase imply less attention for and investment in sustainable energy.
- The final reason for a difficult transformation towards a sustainable energy system lies in the fact that, at least in the Netherlands, conditions for technological innovation are not well arranged. The circumstances for the development of an innovative energy technology depend on an early and consistent government support, high investments and a strong home market (Berg and Slot 2009). Especially the mismatch of government support over the innovation cycle (seed, start-up, expansion) is the main cause of a failing transformation in the Netherlands.

8.5 Energy and Spatial Planning: An Underestimated Relationship

Beside the above financial-technological constraints, the opportunities spatial planning offer, are not yet used to realise a sustainable energy supply. The first descriptive reports on the connection between spatial planning and energy demonstrate a strong focus on the spatial organisation and current and potential land use for energy production (Gordijn et al. 2003), on the land required for every energy source (H+N+S 2008) or on the spatial impacts and constraints as well as the possibilities to realise sustainable energy targets through spatial planning (Hoorn et al. 2010). In these publications energy is not seen as a means to improve spatial quality or realise more beautiful landscapes. The relation between spatial planning and energy (policy) is described as the impact of energy production for spatial planning. By our knowledge, the first study that translated energy potentials into spatial proposals and used them as a design tool was conducted within the framework of the World Gas Conferences 2003 (Itoh 2003) and 2006 (Van Dam and Noorman 2005; Noorman 2006; Roggema et al. 2006). Energy potentials were mapped and combined with each other, providing the basis for spatial interventions in regions.

These pilot studies were elaborated in several subsequent research projects (Van den Dobbelsteen et al. 2007a, 2008a, b, c, 2009a; Tillie et al. 2009; Broersma et al. 2009; Van Etteger and Stremke 2007; Stremke and Koh 2010), illustrating that much higher ambitions are possible in regards to decreasing CO_2 emissions, usage of renewable resources and energy-saving. However, the question remains in which conditions must be established to realise these proposals and whether it is possible to create a completely fossil-free region.

8.6 Towards an Innovative Methodology: The Groningen Case

Several publications point out the necessity to enforce breakthroughs, to increase the importance of local decentralised supply systems and to connect the local systems with regional, national and/or smart grids in order to establish a sustainable energy supply (Droege 2010; Bakas and Creemers 2010; Rifkin 2002; Scheer 2005; Strahan 2009; Pearce 2009; Van de Wiel 2009; Van Timmeren 2006). In current policymaking we are too much accustomed to partial target setting exercises (Droege 2010), as with the EU legislation leading to 20 % renewable energy in 2020 and therefore not equipped to realise a future society functioning without the existence of oil, as Bakas and Creemers describe (2010). The strategic choice to be made is to set a 100 % renewable target, such as the 100 % renewable target set for 2050 by the German minister Röckl. Only this will lead to new urban strategies at a local and individual level now (Droege 2010).

At the local, decentralised level, consumers become producers, made possible by technological developments; a ‘worldwide energy web’ (Rifkin 2002). If, on top of these targets and technological innovations, feed inn tariffs are guaranteed for a longer period of time, as the German system proves (Scheer 2005), a tipping-point will be reached and individual households and farmers will instantly start to invest in wind and solar power. Another condition for success is the certainty that decentralised systems can be connected to higher-level grids, such as a European green grid (Strahan 2009; Pearce 2009), which opens up the possibility to create a ‘mobile smart grid‘ (Van de Wiel 2009), which uses electric vehicles to store energy in times of low energy demand. The advantage of decentralised production of energy is the increase in flexibility and efficiency in energy conversion (Van Timmeren 2006). The European Climate Initiative proposes a connected European grid and breakthrough technologies, such as enhanced geothermal, space solar power, wave and tidal stream power, high-altitude wind power, spray-on solar cells, algae bio-fuel or body power (OMA and ECF 2010). A smart combination of autonomous and heteronomous systems is likely to increase the flexibility of energy systems and make it possible to deal with dynamic circumstances (Van Timmeren 2006), as in case of a sudden absence of one resource, and open the system for the contribution of individual producers of renewable energy (Stremke and Koh 2010).

These theories and research findings inspire the development of a design methodology for fully fossil-free regions. The method consists of three steps: potential mapping, conceptual design, and swarm planning. In each step specific decisions are made (Fig. 8.2). Energy potential mapping investigates

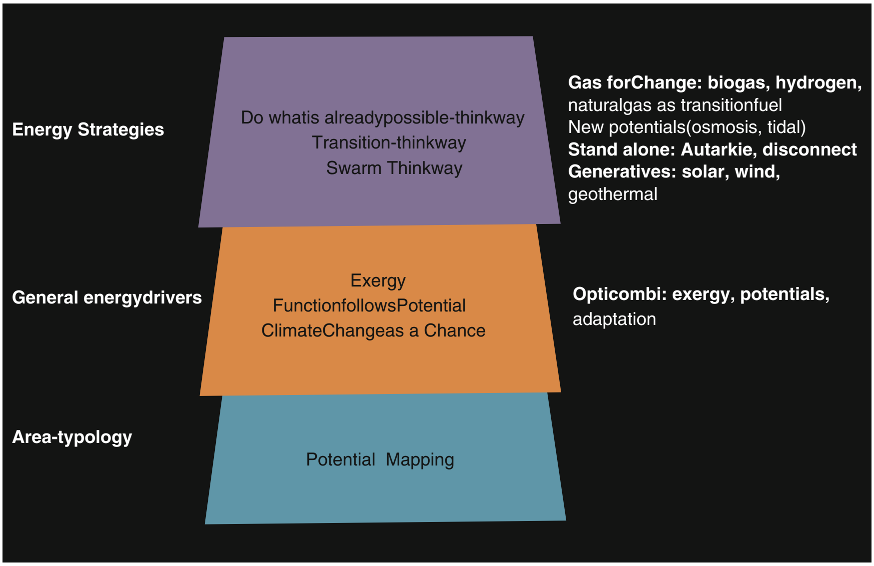


Fig. 8.2 Three steps in the methodology linked with types of decisions

characteristics of the area. The climatic, physical, natural and technical features form the basis for energy analysis and proposed development of the area. In conceptual design (Step 2), general energy drivers are taken into account. Choices need to be made whether exergy principles will be directing spatial order, whether functions follow the potentials analysed in Step 1 and whether climate change adaptation needs to be integrated with energy planning (Stremke and Koh 2010). The last step focuses on realisation. Strategies range from a business as usual model (a), in which the pace of innovations is rather low, to a strategy focussing on transition (b), in which, for instance, gas as transition fuel becomes important, or the Swarm Planning strategy (c), which aims to create breakthroughs and accelerating developments (Roggema 2005, 2008a, b, 2009b; Roggema and Van den Dobbelsteen 2007, 2008; Roggema and De Plaa 2009).

8.6.1 Energy Potential Mapping

As the first step in the methodology is the local specific energy potentials are mapped. This mapping takes place in a couple of steps, as demonstrated, amongst

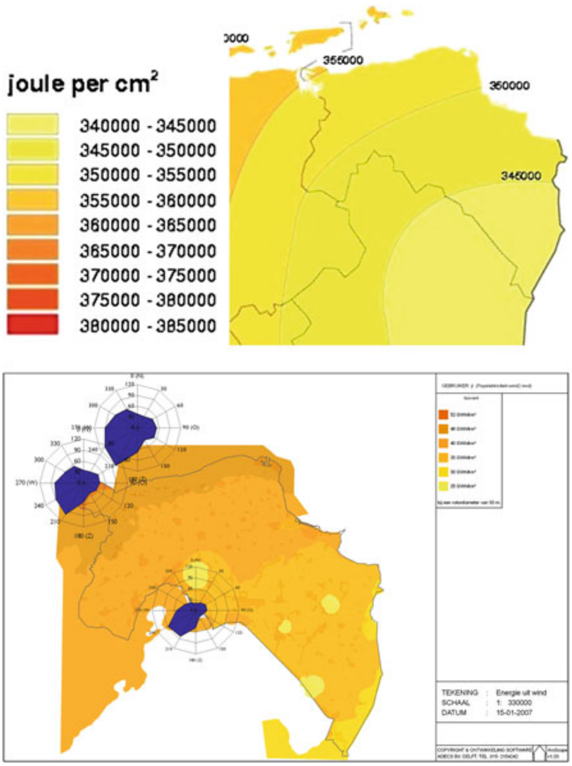
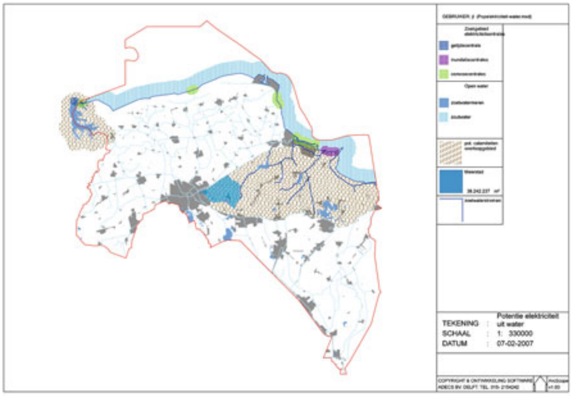
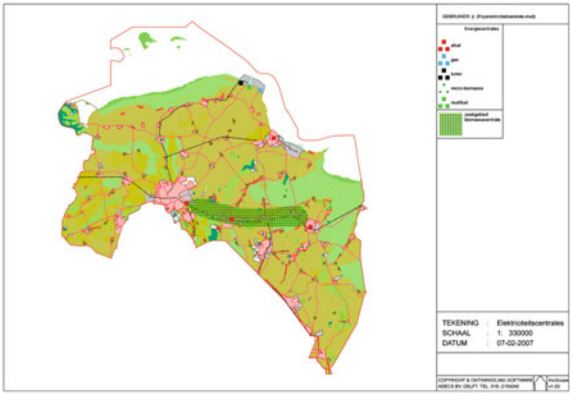


Fig. 8.3 Basic potentials for solar energy, wind energy, hydropower, biomass, geothermal heat (*shallow* and *deep*) and local heat production [Van den Dobbelsteen et al. 2007a, b]

Fig. 8.3 continued

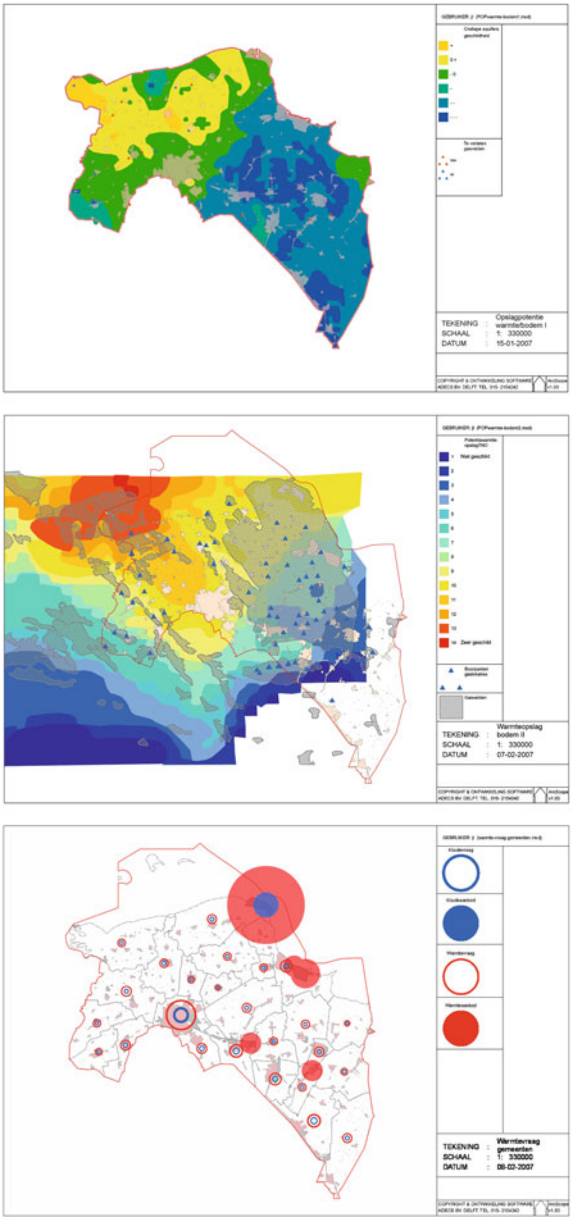




other studies, by the EPM study for the Groningen area (Van den Dobbelsteen et al. 2007b). First, the general basis of the area, such as climatic, topographical, geographical and land use characteristics, is analysed and visualised on maps. Second, based on these local characteristics, specific harvesting potentials from renewable resources are put on maps, such as wind energy, solar energy, hydropower, biomass and shallow and deep geothermal heat as well as available residual heat from industries (Fig. 8.3). Third, two integrated maps are derived: one for the potentials for production of electricity and another, which shows the potentials for heat and cold (Fig. 8.4). These two maps are combined in order to create the so-called 'energy-mix map', on which the combination of electricity and heat potential are shown (Fig. 8.5). Based on this integrated map, spatial interventions are selected on the basis of urgency and effectiveness (Fig. 8.6).

The first step of the methodology focuses on the local potentials of area-specific renewable sources and defining the most optimal locations for different spatial functions. It is potential-driven, which means that the starting point is the possible maximum renewable energy provision instead of an explicit set target.

Fig. 8.3 continued



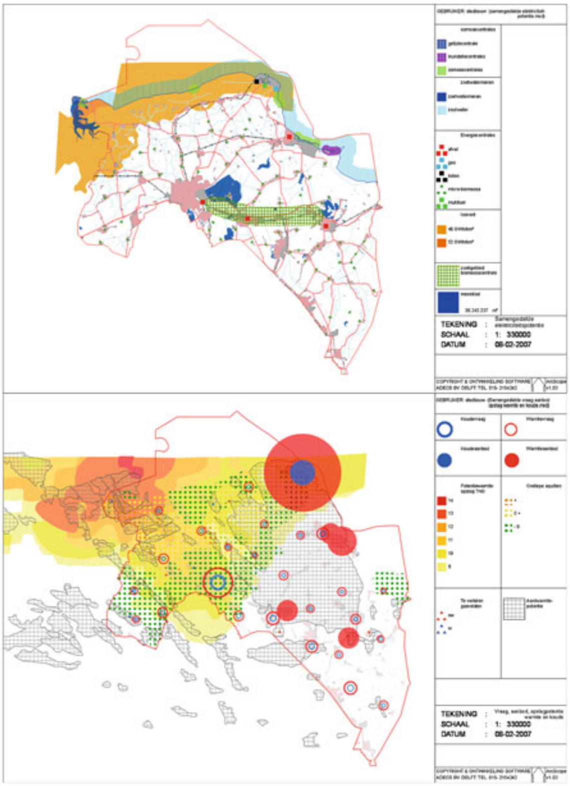


Fig. 8.4 Integration in a potential for electricity production map and a potential for heat and cold map [Van den Dobbelsteen et al. 2007a, b]

8.6.2 Conceptual Design

The second step is the interpretation of potential maps into regional design. Within the setting of the INCREASE conference (Roggema et al. 2008; Roggema 2009a; Roggema and Boneschansker 2010), the researchers explored if a region can be developed that functions without the use of fossil resources and without the import of other energy sources. Taking into account some basic assumptions,[5] it turned out that the entire region can be sustained without the use of fossil resources. The conceptual design (Fig. 8.7) directs spatial distribution of the different types of energy provision as well as the planning of other functions.

Several different sub-regions are distinguished:

The Veenkoloniën ('Peat Colonies') will produce the majority of energy, food and organic material in PV-coated greenhouses, in combination with tall wind turbines. Residual heat from the greenhouses is recycled in closed loops and stored

[5] Examples of these assumptions were: 50 % energy saving with respect to the current demand, a stable population number and an energy budget of 1000 kWh/y per household.

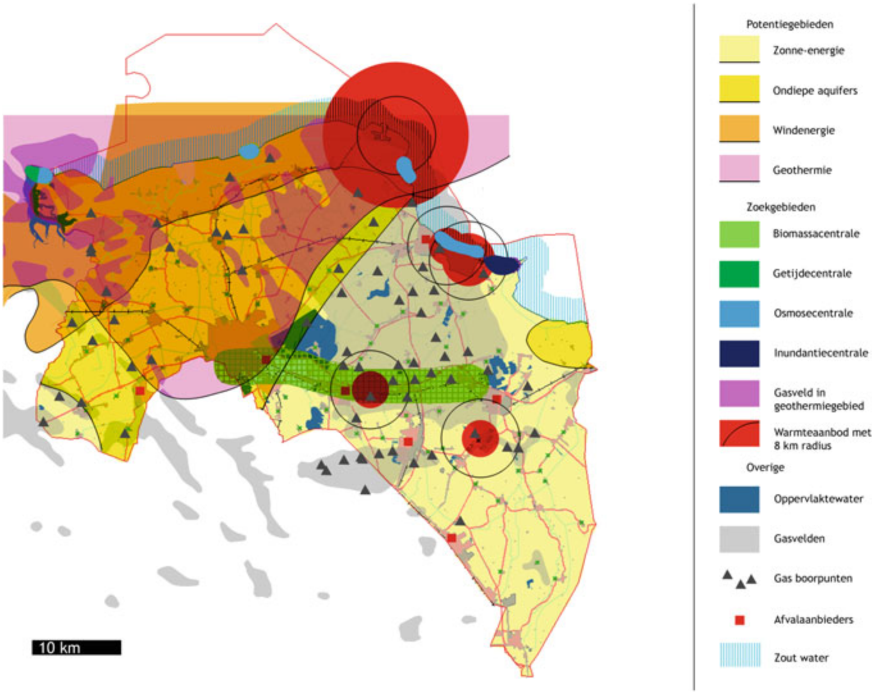


Fig. 8.5 Energy-mix map [image: Van der Grinten 2008; based on Van den Dobbelsteen et al. 2007a]

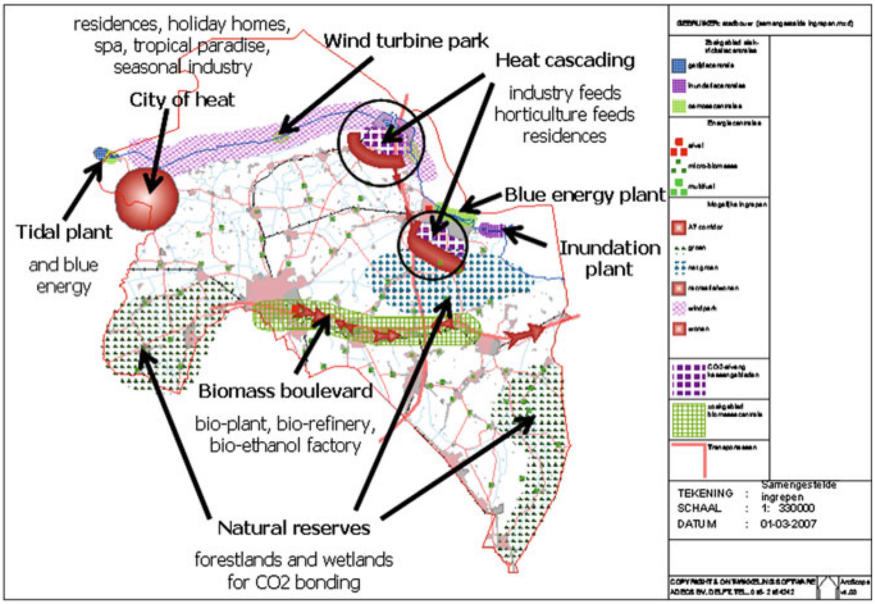


Fig. 8.6 Proposal for energy-conscious spatial interventions [Van den Dobbelsteen et al. 2007a, b]

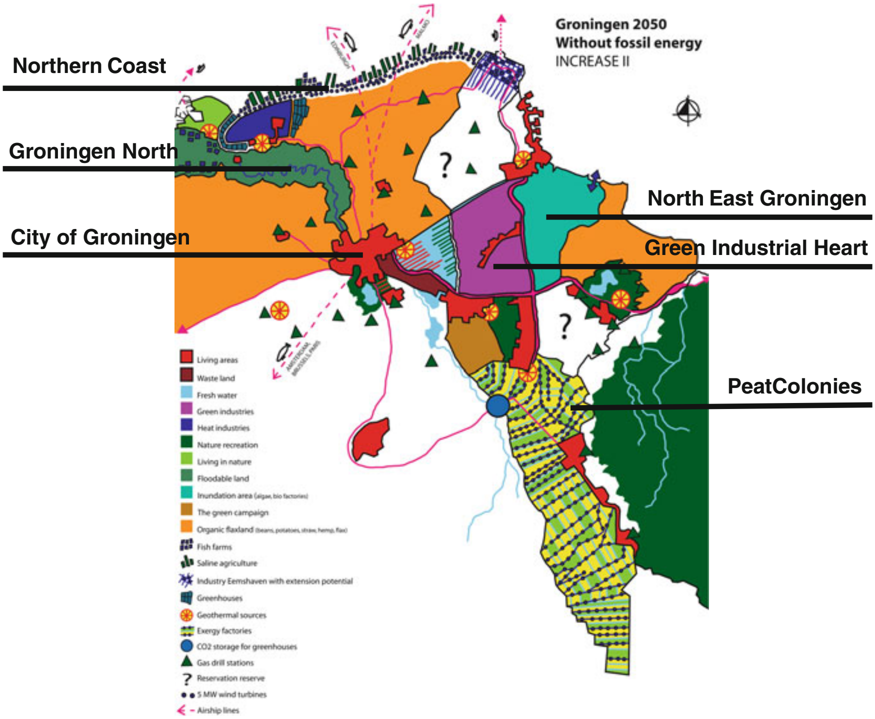


Fig. 8.7 Conceptual design for Groningen area as a fossil-free region as proposed during INCREASE 2010 [Roggema and Boneschansker 2010]

locally; North East Groningen is used for (algae-based) bio-fuel production; In the ‘Green Industrial Heart’ bio-based processing of food, biomass, bio-fuels, organic waste and waste water takes place;

The city of Groningen, which is the provincial capital, will need to transform its existing building stock into ‘e-novated’ (energetically renovated) houses and ‘e-neutral’ buildings. The remainder of the required heat will be provided through heat and cold exchange. Transport will be shifted to light-weight electric means, such as electric bikes, and waste will be fully recycled; Groningen North is very suitable for wind farms and for geothermal heat, but also for locally feasible technologies, such as tidal plants and blue energy plant (osmosis or RED). The potential abundance of geothermal heat in this area provides opportunities for heat-requiring functions, such as greenhouses or shrimp farms;

In front of the Northern coast saline agriculture will be developed for local food production, making use of the saline circumstances here.

This conceptual design, which makes use of the energetic specifications and qualities of different areas, illustrates that it is possible to provide the region with energy without making use of any fossil resource, taking into account the assumptions described before.

8.6.3 Swarm Planning

The final step is the identification of starting-points of realisation. This is necessary because of the fact that a fossil-free region cannot be realised on a short term and that current planning systems tend to focus on a period of ten years maximum [Roggema w. De Plaa 2009]. This planning paradigm is shifting towards a more flexible long-term oriented scheme in which developments are started yet made flexible from that moment on, allowing future dynamics to influence and change the development pathway. This planning paradigm has been called Swarm Planning (Roggema 2005, 2008a, b, 2009b; Roggema and Van den Dobbelsteen 2007, 2008; Roggema w. De Plaa 2009), after the dynamic processes a swarm undergoes after being influenced by few simple rules or incentives. The question, however, remains how to find the points where processes of realisation of sustainable energy provision start. Through the analysis of different network types (water, transport, communication, energy and social) nodes with extra strong and multiple connections may be distinguished. These focal points (nodes) and their zones of influence are the places of 'emergence' (Roggema et al. 2012a), where the probability is highest to realise energy-conscious interventions.

In order to find such focal points networks need to be analysed first. As key characteristics of networks, both randomly evolved and directed ones, the following are mentioned (Newman et al. 2006):

1. Properties of the network increase in quality suddenly, once enough edges are added and certain thresholds can be distinguished when these sudden increase of sub categories appear (Erdős and Rényi 1960);
2. Directed networks, such as the World Wide Web or the Internet, but also many real physical networks, consist of a core (a giant strongly connected component), links-in and links-out as well as other islands and tendrils. All four subcategories represent about a quarter of the network. Broder et al. (2000) drew the bow-tie visualising their findings;
3. The small world effect (Watts and Strogatz 1998) describes the characteristics of networks: if the number of nodes in the network increases, while connected by a short path, the total length of paths will increase logarithmically and a high level of clustering will occur, meaning that two nodes will be connected to each other if they have a neighbour in common;
4. The increase of connectivity of nodes in a network depends on the fitness to compete for links (Bianconi and Barabási 2001). This fitter gets richer phenomenon helps to understand the evolution of competitive systems in nature and society;
5. Robust networks, at least complex biological ones, are formed by highly connected nodes, which are highly clustered and know a minimum distance between any pair of randomly chosen nodes (Solé et al. 2002).

Based on these characteristics and translated to spatial structures the key elements in finding the points of emergence are the number of nodes, the appearance of strong cores with many connections, the fitness of the nodes, and clustering and minimal distances. Following this, a Swarm Planning starting-point can be found by looking at the number, the connections, the clustering, the distance and strengths and fitness of cores, i.e. where important and many types of networks form a node.

As demonstrated by two preliminary research maps with the energy and water network for the Groningen region (Fig. 8.8) several high intensity nodes can be distinguished (Hao et al. 2010). Determining the Swarm Planning starting-points, ultimately these two maps need to be combined with maps of other networks, such as transport, communication and social networks.

However, by combining these two maps and incorporating a threshold of taking into account only the two highest categories, a few strongly connected, combined and clustered cores are distinguished and can be seen as the starting, or focal, points of developments (Fig. 8.9).

It may be concluded that based on the local characteristics the energy potentials can be determined and based on these a conceptual design can be developed. This design can be realised by making use of a new planning paradigm (Swarm

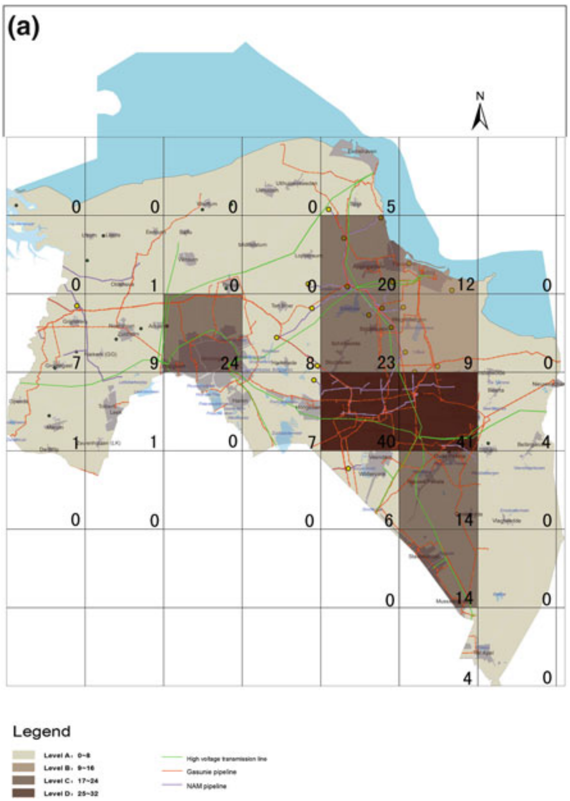
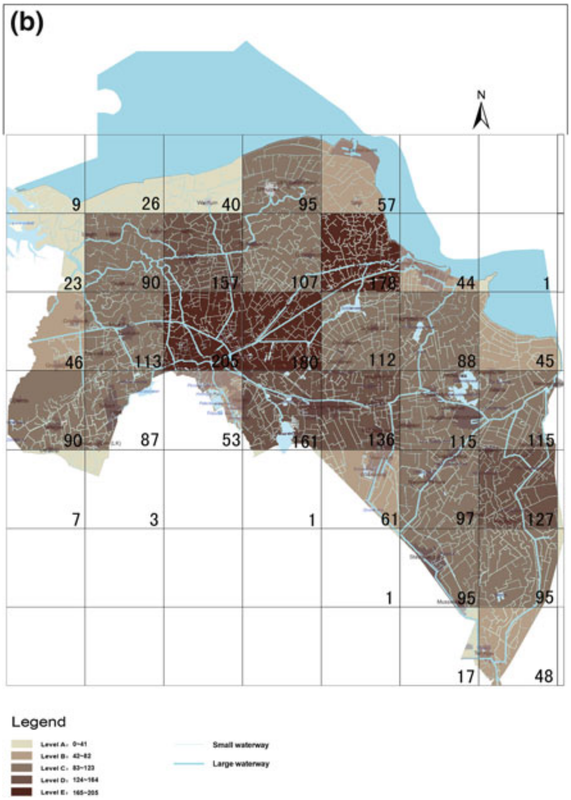


Fig. 8.8 Network analysis of energy (**a**) and water (**b**) [Hao et al. 2010]

Fig. 8.8 continued



Planning), which focuses on determining the starting-points for realising energy-conscious developments rather than create a blueprint for the future.

8.6.4 Findings

Following the methodology presented in this chapter, the results of research conducted can be summarised in terms of avoided emissions and established energy savings. The authors of the Energy Potential Mapping for Groningen region (Van den Dobbelsteen et al. 2007a) estimated that 76 PJ/year can be provided through the provision and cascading of electricity, fuel and heat. The estimated energy demand is 180 PJ, which leads to the conclusion that around 42 % of the current demand can be supplied by making use of locally available renewable resources. The calculated reduction of CO_2 emissions for the Groningen region is even higher. 7190 kilotons CO_2/year can be avoided, equalling 72 %.

Calculations of the conceptual design (Roggema and Boneschansker 2010) were made for 2050 and derived from current uses. 50 % of current energy use is

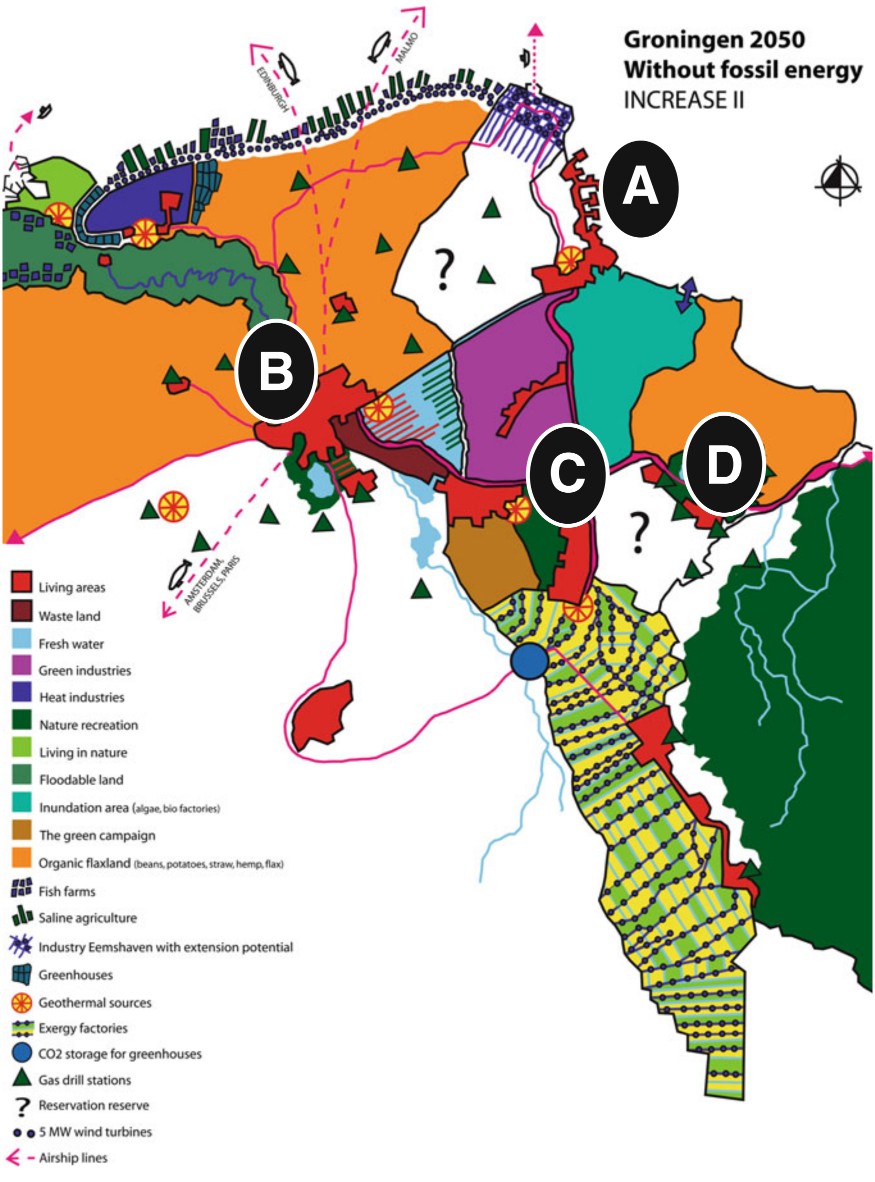


Fig. 8.9 Four focal points based on the network analysis of energy and water

estimated at 91 PJ (which is comparable with the energy potential mapping findings of 180PJ = 100 %) and recalculated for 2050 on a level of 70 PJ, especially because in the conceptual design the power generation through large-scale energy companies is no longer necessary. The calculated renewable energy provision according to the conceptual design is 90–113 PJ, which means that sufficient energy can be supplied to the region. The avoided CO_2 emissions are 100 %, because the objective for the design was a fossil-free energy supply.

The Swarm Planning phase was not calculated yet, because this focuses on the question how to realise the proposed energy supply system. This is a question that will be further investigated in the near future.

8.7 Conclusions

Based on the findings several recommendations can be made. In general, the debate on the realisation of a renewable energy supply is dominated by existing key players, who are willing to change, if at all, at a very slow pace. General comments are that one should implement proven and feasible technologies only. This attitude to energy transition leads to slow processes and innovation-blocking energy companies who have their own interests.

The ongoing transition, from a global sustainable point of view, is too slow because it is often limited to fossil resources: taking the cleanest one (i.e. gas) and trying to compensate the negative effects of others (i.e. coal-fired power plants).

Second, compromises by (inter)national political leaders lead to policy aims in the order of 20 or 30 % use of renewable energy. Because of these agreements the realisation of a fully sustainable energy supply slows down. Research results discussed in this chapter point out that much higher emission reductions and renewable energy deployment are possible and within reach.

The methodology introduced in this chapter, i.e. analysing the local potentials, conceiving a conceptual design and aim for an approach to breakthrough realisation, increases the implementation of renewable energy resources and serves more ambitious and real objectives at the same time.

It may be concluded that Swarm Planning offers the potential to implement adaptation measures in spatial planning processes, but it is also capable of accelerating mitigating climate change.

The network analysis presented in this chapter requires further elaboration, especially on integrating and combining different networks, such as transport, communication and social networks.

An interesting question is how the process of development continues after the start of transition at a certain point in space and time. The process after the initial intervention determines the development. It is probable that ‘theory of rumours of epidemics’, like explored by Nekovee et al. (2007), Draief and Maoulié (2010) or Gladwell (2000) may be very useful to gain more insights.

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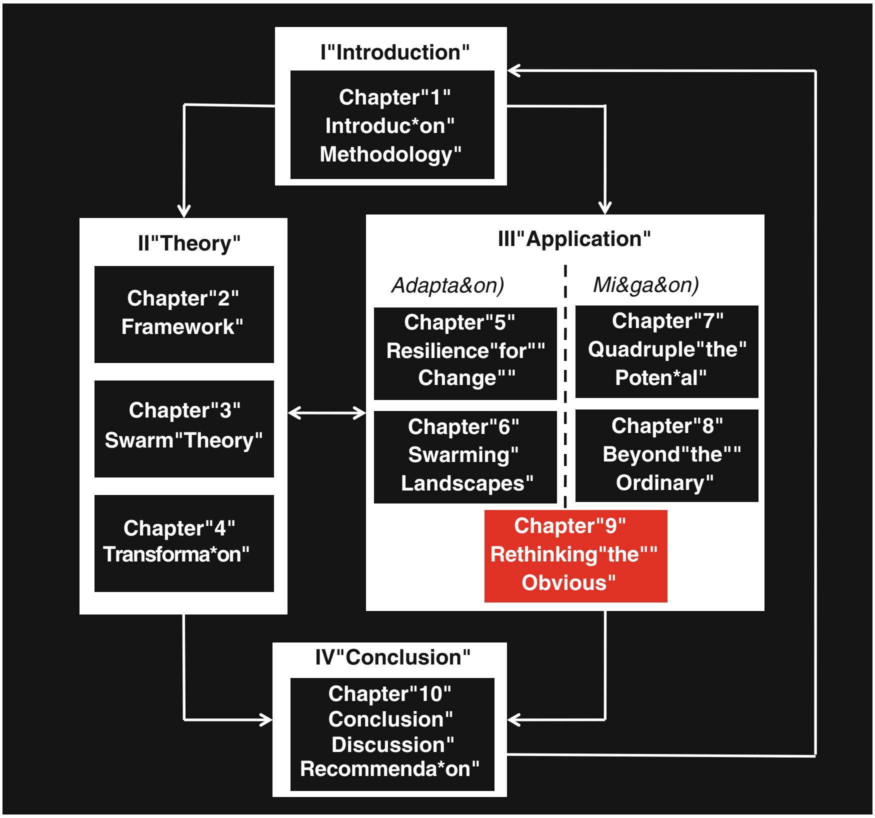
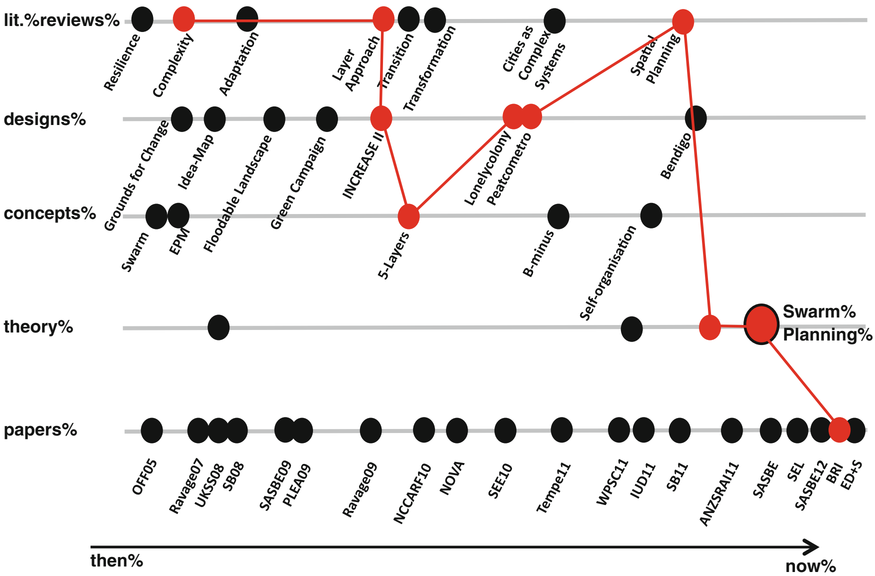
The Bridge: Eight–Nine



Chapters 5–8, focused on the application of the Swarm Planning Framework for climate adaptation and climate mitigation respectively. In Chap. 9 the theoretical basis of Chaps. 2–4 and the findings resulting from Chaps. 5–8 are brought together and deepened. This leads to the development of a comprehensive framework, in which aspects such as dual complexity (the whole and the components), the Five Layers and complexity concepts (such as emergent patterns, fitness landscape, self-organisation and tipping points) are merged with concrete spatial elements and with two step-by-step approaches to use the framework in practice.

As mentioned before, the Swarm Planning Framework builds on two pillars: (1) the layer approach and (2) complexity. Each layer in the layer approach represents a specific time dimension, which accommodate spatial elements in a suitable layer. Two of the five layers focus on identifying a strategic intervention capable of changing the entire system, while the other layers attribute adaptive properties to individual spatial components. The spatial system is supported to move from an unstable state, which for instance can be reached through external impacts of climate change, towards a state of higher adaptive capacity. The Swarm Planning Framework assists self-organisation of spatial systems in two ways: it assists change in spatial land-use over time and it catalyses the free emergence of autonomous and more resilient developments.

In this chapter the Swarm Planning Framework is used in two pilot designs, in which each are compared with the results of their accompanying regular planning processes, for the province of Groningen and the Peat Colonies respectively. The comparison illuminates a couple of elements. First, the Swarm Planning Framework offers serious advantages to deal with climate change in spatial planning. Second, the process analysis of both pilot designs shows that adjusted planning processes are required to achieve these results. In this respect, a iterative planning process, such as executed in design charrettes is preferable over linear planning processes.



Chapter 9
Swarm Planning for Climate Change: An Alternative Pathway for Resilience

9.1 Introduction

Although there are an increasing number of extreme events (www.emdat.be), humankind has learnt how to deal with their immediate impacts. This is illustrated by the fact that the number of casualties as a result of extreme weather dropped from 240 million (in 1920) to three million (in the last decade). Nonetheless, there is still a need for communities to improve their capacity to adapt to forthcoming climate events, particularly if adaptation pathways substantially reduce carbon footprints.

A growing attention for the adaptation to climate change can be witnessed in current spatial planning practice. However, despite this attention, the question is whether spatial planning frameworks and approaches are sufficiently equipped to include strategies that deal with uncertainty and that are capable of anticipating an unpredictable future. In this chapter swarm planning theory (Roggema and Van den Dobbelsteen 2008; Roggema 2012a, b) is taken as the starting point to be used in two examples of actual regional design. The theory is applied and tested in practice and the results are presented here.

This chapter focuses on the potential benefits that a swarm planning approach can offer. This is particularly relevant to designing for both a post-carbon scenario

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R. Roggema, *Swarm Planning*, Springer Theses, DOI: 10.1007/978-94-007-7152-9_9,

(the period after dominance of use of fossil energy resources, authors' definition) and a pre-adaptive scenario (the period before preparations to anticipate climate change impacts are taken, authors' definition) landscapes.

9.2 Methodology

The research is presented here in the following parts (Fig. 9.1):

- The characteristics of both climate change and spatial planning are briefly analysed.
- A problem statement is formulated on the basis of the analyses (Sect. 9.4).
- The theory of swarm planning as a potential solution to tackle the problem is explained resulting from two pillars: The Layer Approach and Complexity theory.
- The results of the research are discussed. Swarm planning is applied to two case studies and the results are compared with the outcomes of regular planning processes for each of the cases. The first case study compares the process and results of the regional plan for the province of Groningen, the Netherlands, finalised in 2009 (Provincie 2009), with the process and content of INCREASE II (Roggema and Boneschansker 2010), an example of swarm planning, which has been executed in 2009. In the second case study the planning process and the content in the area development of the Peat Colonies, an ongoing process between 2002 and 2012 (Van Eerten et al. 2008), is compared with the process and outcomes of the Hotspot Peat Colonies (Broersma et al. 2011), finalised in 2010, which represents also an example of swarm planning.
- Conclusions are drawn on the benefits and disadvantages of using swarm planning theory for planning processes.

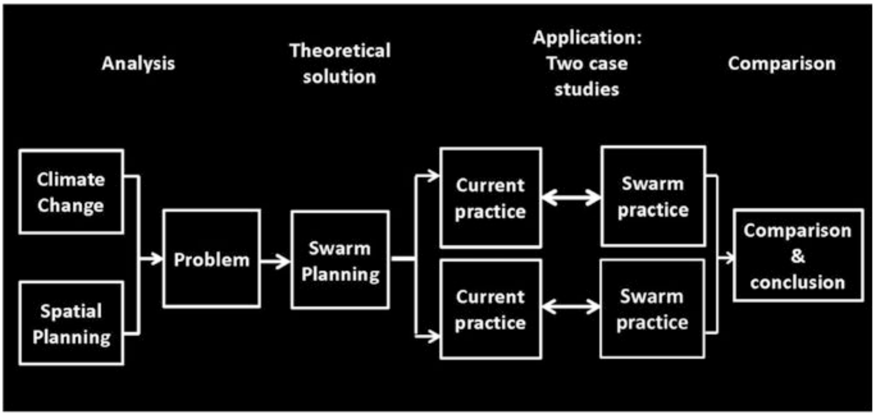

Fig. 9.1 Overview over the research process

9.3 Analysis

9.3.1 Climate Change

Recent literature (VROM-raad 2007; Commonwealth of Australia 2007) describes climate change as a 'wicked' problem. Defined by Rittel and Webber (1973). Wicked problems are problems with infinite repercussions that cannot be tracked because there are too many. Because of that, these problems may generate non-linearity and surprise. Climate change performs sudden significant changes that cannot be explained in a linear, predictive way. Its non-linear processes and developments cause stepped changes, which are represented as a staircase (Fig. 9.2) (Jones 2010, 2011a, b).

9.3.2 Spatial Planning

As demonstrated elsewhere (Roggema 2012a, b) dominant discourses in planning theory do not take wicked problems as major subject. A total of 275 articles, published in 2010–2011 in the Journals of *Planning Theory* (43), *Planning Theory and Practice* (34), *The Australian Planner* (45) and *European Planning Studies* (153), being the leading theoretical and practice oriented academic planning journals originating from two different continents, have been analysed. The articles were judged on four criteria informing whether in the articles theories, concepts and strategies are discussed that potentially can deal with wicked problems. The following criteria are distinguished:

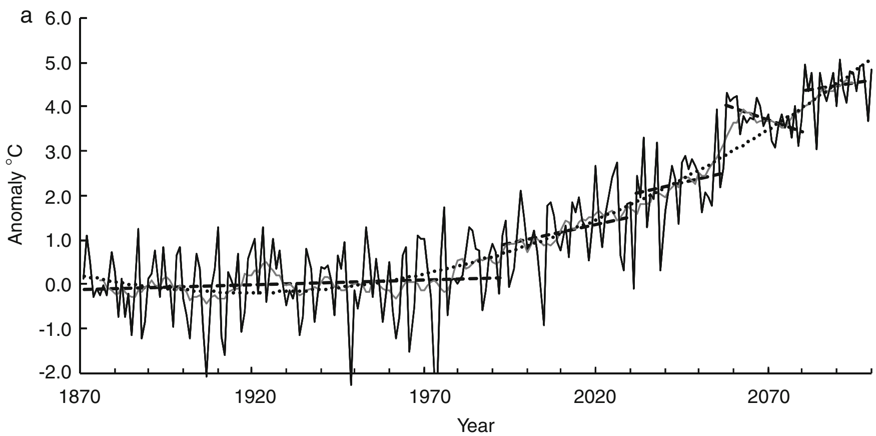

Fig. 9.2 Step and trend analysis, based on dummy data, illustrating one of many analyses, showing the 'staircase' of climate change (Jones 2011b)

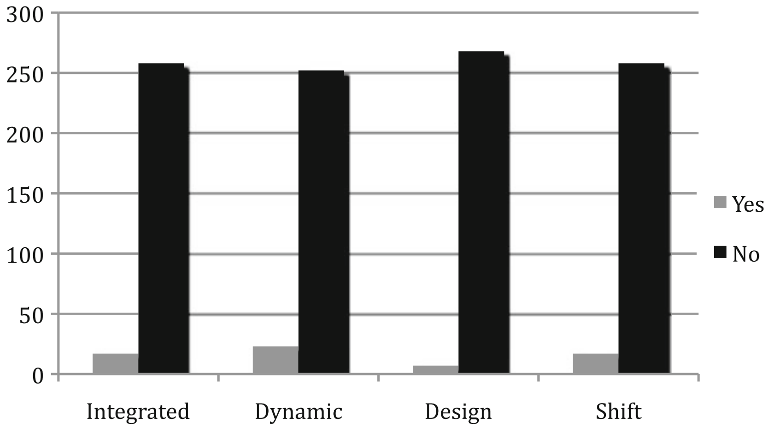

Fig. 9.3 Number of articles in planning theory, planning theory and practice, Australian planning and European planning studies (2010–2011) that do and do not discuss integration, dynamics, design and a paradigm shift

- **Integration (vs. thematic, specific, single subject)**: Does the article approach problems in an integrative way or is it focusing on a specific theme or subject?
- **Dynamic (vs. static)**: Does the article assume that planning tries to continue the current state or focuses it on dealing with changing environments or subjects?
- **Intervention (vs. regulatory)**: Does the article discuss a design approach or a spatial intervention or does it focus on describing regulations and institutions?
- **Paradigm shift (vs. status quo)**: Does the article describe planning as it is currently and/or was in the past or does the article focuses on identifying a paradigm shift?

The analysis finds that articles, addressing dynamic, integrated, intervention topics and paradigm shifts are rarely found in recent planning literature (Fig. 9.3). In reverse, the vast majority (95 %) of the academic publications address planning as stationary responding to tame,[1] linear problems.

This analysis indicates that few examples emphasise non-linearity, dynamism, change or self-organising principles as a part of theory or frameworks for spatial planning (e.g. Miraftab 2009; Newman 2011; Davy 2008). Although the analysis is quantitative and looks only at four out of many academic journals, it gives insight into only the mainstream debate but not other academic efforts to create planning typologies which address complexity and non-linearity, i.e. Innes and Booher (1999, 2004, 2010). These authors advocate a collaborative approach to overcome

[1] Tame problems are referred to as problems that: "have a relatively well-defined and stable problem statement; have a definite stopping point, i.e. we know when the solution is reached; are met by a solution which can be objectively evaluated as being right or wrong; belongs to a class of problems which can be solved in a similar way; are met with solutions, which can be tried and abandoned (Conklin 2001).

non-linearity. Apart from responding to non-linearity in planning, many sustainable eco-designs have been realised. Despite the fact that many of these developments improved sustainability in neighbourhoods, such as in Sweden (Flaggenhusen in the Western Harbour of Malmö or Hammarby Sjöstad near Stockholm), Germany (Freiburg's Vauban, and Rieselfeld districts), the Netherlands (Lanxmeer (EVA), Ecolonia) and several others, the question is whether these eco-designs are prepared for surprises and the impacts of climate change. All of these examples are built within the current sustainability paradigm, which is not very well prepared for external shocks. In the same category, the development of eco-blocks (Fraker 2008) can be counted, a holistic approach to (re-)develop China's superblocks to become self-sufficient.

9.4 Problem Statement

Interpreting current 'schools of urbanism' (Fraker 2007) illustrates the difficulty of dealing with dynamic, uncertain or changing circumstances. None of the six distinguished urbanisms, probably with the exception of hyper-modernity in its "search for enabling fields that accommodate hidden processes", address change over time. Nor do they address change that cannot be predicted, i.e. several climate impacts. A useful typology for assessing different categories of uncertainty (e.g. goals and technologies known or unknown) was developed to support planners selecting the style of planning depending the sort of uncertainty planners are confronted with (Christensen 1985). If the 'wicked' problem of climate change is mapped onto this scheme, it is likely to be placed in the corner where the goal is not agreed (the unpredictability of many climate change impacts means it is difficult to agree on solving a certain problem) and the technology unknown (climate change impacts can be unprecedented making existing technologies inappropriate). According to Christensen, these types of chaotic problems require leadership and problem finders. This quarter of Christensen's scheme is also the least developed planning response of the four categories. Therefore, in planning for this category of problems, there is space to develop an alternative planning approach. This alternative approach would address the uncertainties in determining goals and technologies, but at the same time directing the spatial responses. A possible theoretical approach has been developed: swarm planning (Roggema and Van den Dobbelsteen 2008; Roggema 2012a, b). Building on this theory. The question is its application in practical planning processes. This chapter considers the usefulness of swarm planning in actual regional design.

9.5 Swarm Planning

The swarm planning theory (Roggema 2012a, b; see also: http://swarmplanning.com) was developed to be able to plan for increasingly changing environments. One of the main drivers for these changes is climate change. In order to develop a planning approach, which is able to accommodate non-linear processes and self-organisation, it learns from swarm behaviour, because swarms are capable to adapt to sudden changing environments.

Swarms in nature have been extensively studied. The behaviour of bees, ants, birds and termites is used as an example for human interactions in organisations and society (Fisher 2009; Miller 2010). The core of these theories is that (i) swarms function according to a few very simple rulesSimple rules[2] and (ii) swarms perform as highly resilient systems (Van Ginneken 2009). It develops emerging patterns and structures, which lessen the impact of uncertainties, complexity and change. Miller (2010) defines four principles of a smart swarm: self-organisation, diversity of knowledge, indirect collaboration and adaptive mimicking (coordinate, communicate, copy). In current human society, swarm characteristics of connectivity, networks and the World Wide Web are becoming more important and will increasingly shape the way we live in the future. As Bonabeau et al. (1999) demonstrated: "autonomous, emerging patterns and 'parallel distributed' co-evolution will empower collective self-organisation and enhance synchronicity".

Swarm theory is rarely used in the design of the built environment. In one stream of research and design practice, swarm behaviour is applied to buildings through programmatic labelling and tagging of building components. This enables buildings to be customised to temporary desires or changing demands. The fluidity of the designs represents the constant adjustability of the individual elements in the building (Oosterhuis 2006, 2011).

In regional designs, swarm theory is applied in few cases. When the landscape operates as a swarm it is capable of changing its configuration flexibly while the elements it consists of remain unchanged. Through this capability the landscape can adapt 'better' when external shocks, such as resulting from climate change, occur. This design approach has been subject to a growing body of literature (Roggema 2008a, b, 2009a; Roggema and Van den Dobbelsteen 2007, 2008).

[2] As an example, the very simple rules in nature (for birds and fish) are (1) Stay as close as possible to the middle, (2) Move in same direction and with same speed as the others and (3) Stay 2–3 body-lengths away from neighbours.

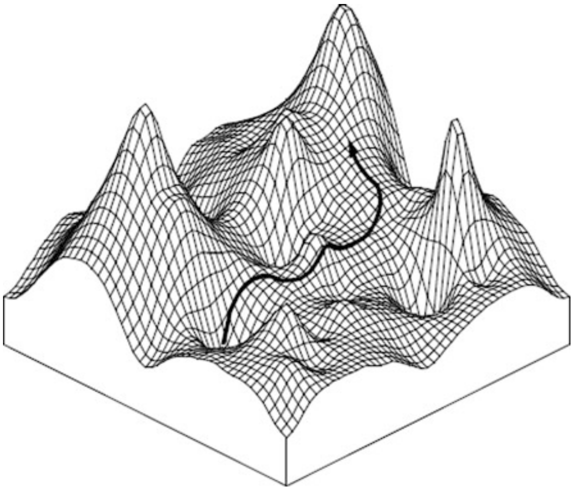

Fig. 9.4 Fitness landscape (Cohen and Stewart 1994) showing a complex system moving from a less favourable to a favourable position or attractor

9.5.1 Complexity

Swarm planning theory consists of two pillars: a layer approach and the use of complexity principles. Complexity theory is a broad scientific field. In this chapter only one concept will be used, the property of complex systems to increase their adaptive capacity. The way these regime shifts occur has been extensively studied (Walker et al. 2004; Scheffer et al. 2009; Folke et al. 2010). Systems remain in a stable equilibrium for a long period, changing in a linear and slow manner. External pressure can move them away from this equilibrium (towards 'the edge of chaos' (Mitchell Waldrop 1992), before crossing over, in a rapid and non-linear way, to another stable state. This regime shift is visualised as a fitness landscape (Fig. 9.4). The system searches its way to reach the highest levels in the fitness landscape where adaptive capacity is highest.

Complexity concepts are currently not used to influence the behaviour of the city. Initial research (Roggema 2012a, b) identifies) how systems can be stimulated to move to the highest levels. Two levels of *dual complexity* (Portugali 2000) are used to enhance adaptive capacity: the system as a whole and the individual components.

1. The system as a whole can be influenced most when an external pressure, (i.e. those exerted by climate change), has moved it away from equilibrium. At the edge of chaos the system approaches a bifurcation point, where the system diverges and several future stable states become possible. Here, at this tipping point (Gladwell 2000) the intervention in the spatial system needs to 'tip' the system in the most favourable direction.
2. Individual elements, attributed with properties of Complex Adaptive Systems (see Roggema 2011), perform emergent behaviour and are together capable to

self-organise. In combination with the right intervention individual components will reconfigure the system to let it 'flip' to a state of higher adaptive capacity.

When these processes are facilitated through spatial planning the adaptive capacity in regional plans is improved.

9.5.2 The Layer Approach

The second pillar is the layer approach, developed in the Netherlands (Frieling et al. 1998). This links spatial elements to specific time rhythms. Originally the following layers were distinguished:

- The layer of the substrate (erosion processes and water systems) is assumed to change over centuries.
- The network layer includes transport, energy and ecology. The timeframe of this layer is approximately 100 years.
- In the human occupation layer (residential, industries) changes take place in a generation (20–50 years).

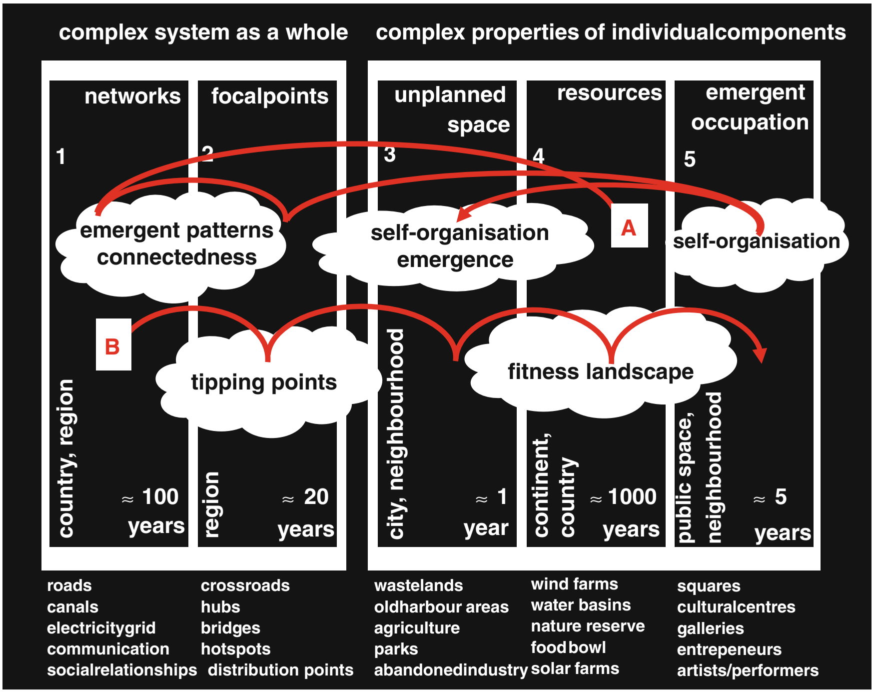

Fig. 9.5 The swarm planning framework (Roggema 2012c)

- The ‘layer of the public domain’, added to the original three layers by De Hoog et al., provides impulses at strategic points (nodes, centres) in the urban system. This is estimated to occur in intervals less than 20 years (De Hoog et al. 1998).

Apart from these sources, literature regarding the Layer Approach is limited (Van Schaik and Klaasen 2011). However, the approach offers a unique possibility for planning to address different time-horizons and/or sudden (steps of) change. The number and types of layers is amended and extended in the swarm planning theory.

9.5.3 Key Elements of Swarm Planning Theory

The key elements of swarm planning theory (Fig. 9.5) are:

- *The whole and the parts*. Increased adaptive capacity can be created by intervening in the whole system at strategic nodes and by improving the adaptive behaviour of individual elements.
- *Layers*. The five distinguished layers (see Table 9.1) are linked to specific time horizons, but are also connected to geographical entities. Moreover, in Fig. 9.5 examples (not limitative) of specific landscape elements belonging to each layer are identified.
- *Complexity concepts*. From the combination of layers and complexity at certain levels, in time and space, specific concepts are likely to emerge. For instance, it is likely that in networks new patterns emerge, resulting in increased connectedness. Or, in places where many different functions are apparent, new combinations arise as a result of self-organisation.
- *Application*. The swarm planning theory can be applied in several ways, of which two are represented through the red lines in Fig. 9.5. Option A relates closest to the original layer theory, starting from the underground/resources, after which the networks-, nodes- and occupation-layers are considered. The ultimate layer of unplanned space fills remaining unused space. Option B starts with influencing the whole system through the network- and nodes-layers. The localities of these two layers subsequently determine where to preserve unplanned space, after which space for resources and emerging occupation patterns fill the remaining.

9.5.4 Application of the Theory

The practical application of the theory uses the time-dependent spatial layers. Every layer is linked to spatial elements with corresponding timeframes within which they tend to change, recycle or rebuild. The five layers together span the total required time dynamics: from very quick changing elements to the ones changing over very long periods. The first two layers, networks and focal points,

Table 9.1 Properties and time-horizons of the five layers

Layer	Name	Properties	Time horizon	Reference
1	Networks	Water, energy, transport, communication	100	Bianconi and Barabási (2001), Barabási (2002)
		Carriers of information, matter and energy		
		Amount, quality and fitness determines connectivity		
		Higher connectivity lead to higher adaptive capacity		
2	Focal points	Inter-linkages and co-location of multiple resources nodes change suddenly due to altered networks or a strategic addition	20	Castells (1996), Graham and Marvin (2001), Biggs et al. (2010a, b), Ryan et al. (2010)
		Number and fitness of nodes, strong cores with many connections, which cluster and minimise distances, determine the start of a system change		
		High potential for emergence of innovations and adaptations		
		Novel arrangements in close proximity enables learning and self-organisation		
		Require a catalyst to encourage innovation		
		Source for dispersing innovations		
3	Unplanned space	In the proximity of the focal points	1	
		Land use is deliberately not determined		
		Wastelands, temporary use or underutilised space		
		Highly dynamic		
		Respond to unforeseen or unpredictable change in very short period		
4	Space for resources	Energy, food, water produced and stored	1000	
		Extremely slow transformation		
		Anticipate increase in demand or a potential decrease of production capacity		
		Continuously capable to adjust the spatial sizes and configurations		
		Small-scale mosaic of functions		

(continued)

Table 9.1 (continued)

Layer	Name	Properties	Time horizon	Reference
5	Emergent occupation patterns	Changing land use, incubation areas, old docklands or gentrified neighbourhoods New unplanned patterns emerge Intensity of networks and functions to enhance interactions Combination and density spatial entities interact, self-organise and emerge Intensity to interact and space is not confined Heterogeneity improves flexibility and agility Many interactions and unintended encounters happen, supporting easy change, enhancing adaptive capacity	5	

focus mainly on the strategic intervention, while layers three, four and five describe collective behaviour of individual components. Table 9.1 gives an overview over the properties of the five layers.

Swarm planning, through practical application of the five layers, provides the opportunity to link spatial elements of different time dimensions collectively to a time rhythm they join. This is important because it includes spatial elements that are usually 'forgotten' in the planning process (surprises or unexpected changes). The connection of layers to one of the dual complexities supports the landscape to perform complex adaptive systems behaviour. This enables the system, when appropriate, to reach a state of higher adaptive capacity.

9.6 Comparing Regular Planning with Swarm Planning

Swarm planning theory has been used in two case studies, the 'Zero-Fossil Region' and the 'Net Carbon-Capture Landscape', both located in the Netherlands. Each of these are compared with an ordinary planning process, which ran parallel to the case study process, respectively the Regional Plan for the province of Groningen and the Agenda for the Peat Colonies.

9.6.1 The Province of Groningen

The province of Groningen is the northernmost province of the Netherlands. The total population is 581,192 inhabitants and the total size of the area is 2,960 km^2 (www.overheidingroningen.nl). The major climate threats resulting from global warming are flooding as result of sea level rise in combination with high tide and storm surge, inland flooding as a result of extreme and prolonged rainfall events and weak inland levees and long periods of drought in combination with increased evaporation due to heat (Alterra et al. 2008). Moreover, the area currently contributes to global warming through emissions of GHG's: electricity is generated from coal and gas, households use natural gas for space and water heating and cooking, transportation relies predominantly on petrol. The landscape is flat and dominated by agricultural use. Significant parts of the province are below current sea level, which requires a strong coastal defence system. The major city is the capital Groningen, where the majority of the people live and major employers, such as the hospital, are found. There are two major harbours with industrial activities, Delfzijl and Eemshaven. The province borders the Wadden Sea, a nature reserve and World Heritage Site. Within its boundaries the Dutch natural gas reserve is found and is currently being depleted.

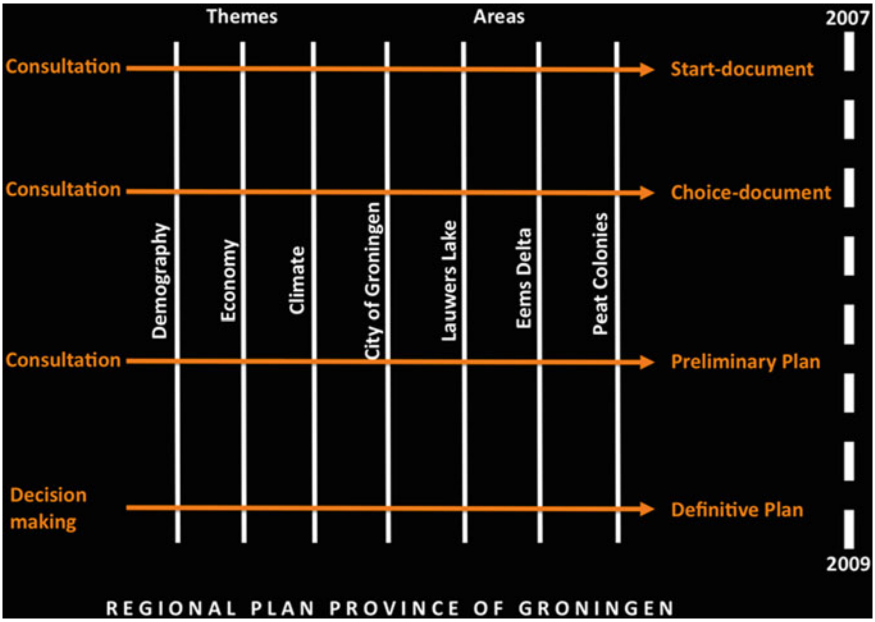

Fig. 9.6 Plan-process regional plan Groningen

9.6.1.1 Regional Plan

Process

The most recent regular planning process (Fig. 9.6) for the Groningen area ran between 2007 and 2009. The process consisted of four subsequent phases, from the start document until the final plan (Provincie 2009). The process was organised around three major themes (demography, economy and climate) and four focus areas. In each of the phases these topics were central, they did not change and were subject to public consultation. The majority of consultation carried out was reactive: the government prepared proposals and plans, which the public and selected stakeholders could provide their opinions and feedback. This straightforward process ended when the regional council adopted the final plan mid 2009.

Content

The planning process led to a plan in which the following priorities were set: allocation of new living areas, economic development, development of plans that deal with a shrinking population, conservation of landscape values, preservation of agricultural functions, development of some new infrastructure, such as several bypasses and ring-roads, as well as upgrading a regional freeway, strengthening the role of the capital, building of two new coal-fired power-plants and the focus on energy saving and GHG emissions reduction. However, the vast majority of allocated functions remain unchanged from former regional plans and the plan

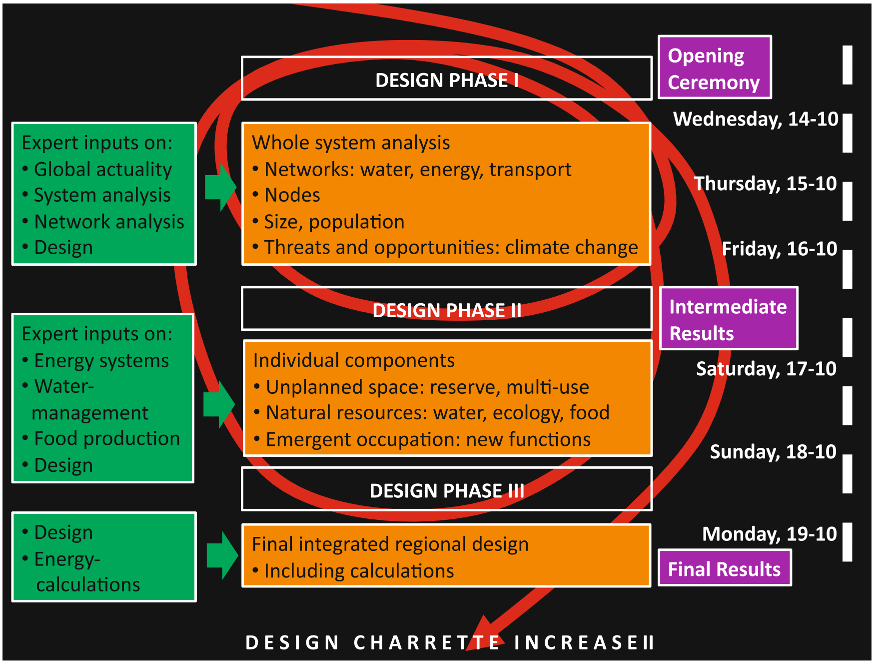

Fig. 9.7 Process design charrette Increase II

lacks inclusion of climate adaptation strategies and measures. The plan is mainly seen as a configuration of functions (in 2D) and arranges areas next to each other. The land-use of every acre is defined and secured through the lifetime of the plan, implying that unexpected developments are difficult to incorporate at a later stage.

9.6.1.2 Zero-Fossil Region

Process

A design charette was held with the purpose of designing a region, which does not use fossil resources (Roggema 2009b). This design charrette was held in China and brought together an extraordinary group of international acknowledged scientists and regional policymakers from Groningen area.[3] Although the focus of the charette was on a regional plan for Groningen, the design charrette was organised in China because:

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[3] Although the focus of the charette was on a regional plan for Groningen, the design charrette was held in China: (i) to create an atmosphere where every participant was away from daily routines; (ii) to increase the commitment of participants (they had to opt in and were self funded) (iii) to support China with innovative ideas on how to develop without having to emit greenhouse gases.

1. To create an atmosphere where every participant was away form daily routines;
2. To increase commitment of participants, as they didn't get paid and needed to provide for their own airfares;
3. To support China in reaching out innovative ideas how to develop without having to emit greenhouse gases.

The structure of the charrette (Fig. 9.7) was designed to be challenging and had an iterative character, represented by the red spiral in the background of the scheme. It started with an official ceremony to set the scene, to encourage participants to perform and to illuminate the importance of the charrette. In the first three days the 'whole system' was analysed and designed. The networks of energy, water and mobility were specifically subject of research, allowing identification of the nodes with highest connectedness. In this stage the network analysis is related to the climate change threats, identifying opportunities to anticipate future impacts and implement mitigation strategies. The design at a level of individual components took place in the following two days, focusing on the role of the energy and food demand and supply as well as identification of areas that could be taken out of the spatial equation: areas for reservations or with potential for multiple use. During this phase calculations were started on the amount of required energy, water and food and the potential to produce these within the boundaries of the design. The final day was used to finalise the calculations and prepare for the final presentation. The iterative character of the process made sure that results of design-phase I were an inextricable part of latter phases, as were design phase II results for the final stage of the process.

Content

The swarm planning approach is used in the design charrette and led to an integrated design (Fig. 9.8), in which the network analysis (the network and focal points layers) and climate change threats are related to each other in three different ways (Roggema and Boneschansker 2010):

- The places where dikes and main rivers or canals cross (e.g. combinations of the transport and water network) identify the nodes where the coastal defence system evolves in a resilient multilayered system. These are the places where the flood risk from sea is mitigated and safety can be increased. The design proposal creates zones inland where seawater, if required, can enter. These spaces, found in the North-western (Lauwers Lake-Reitdiep) and North-eastern (Delfzijl-Eems Delta) areas are currently mainly in use as agricultural grounds. However, in case of a storm surge or overflow new land can be formed by heightening processes of sedimentation of sand and clay particles (building with nature, http://ronaldwaterman.com/page10/page10.html). Where local potential to supply renewable energy is linked with infrastructural network (energy, traffic) tidal (near Lauwers Lake) and osmosis (near Delfzijl) plants are proposed. These plants produce electricity, which can be used for industrial and residential purposes;

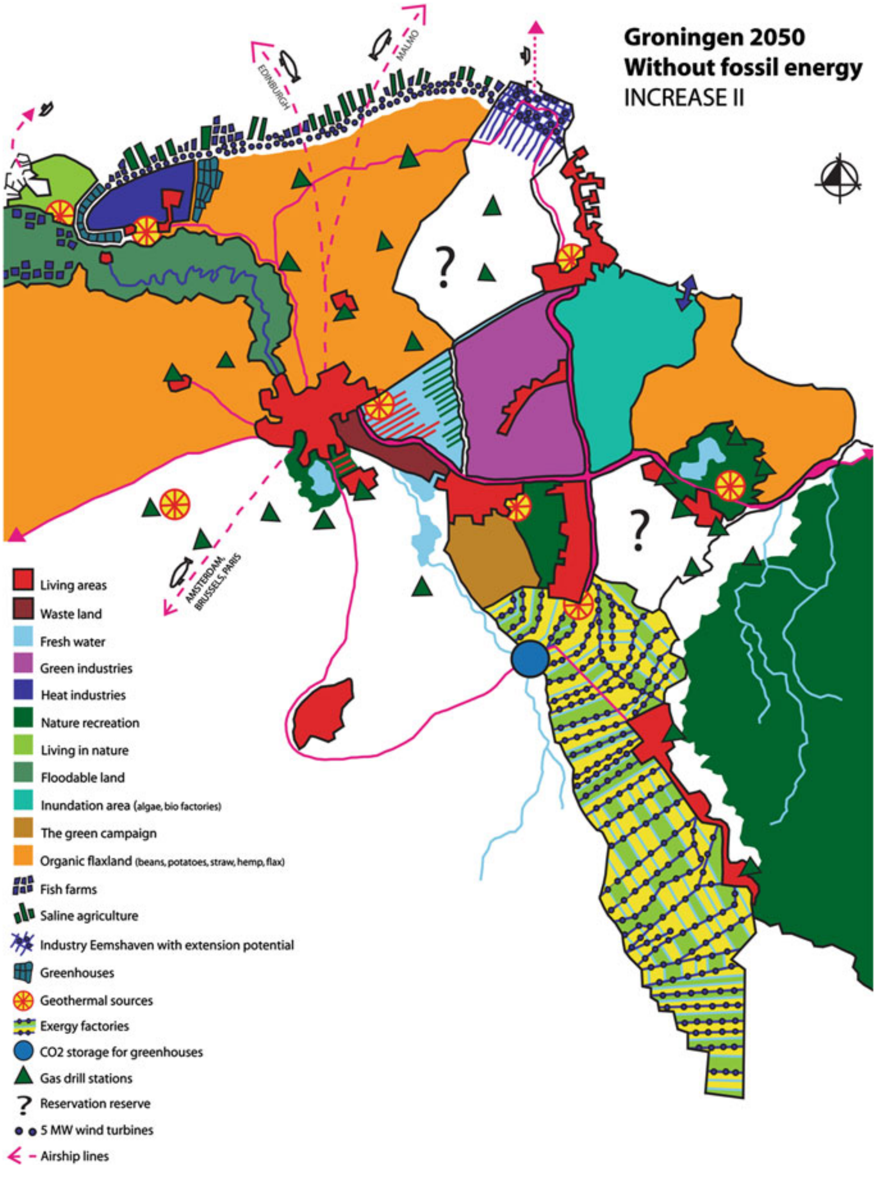

Fig. 9.8 Spatial design for the Dutch province of Groningen without the use of fossil resources

- The densities of the water-, energy- and traffic-networks are highest in the southeast, leading to many nodes with high connectedness. Therefore, it is highly likely that, after initial start-ups in several of these nodes, local initiatives to supply energy and food will emerge autonomously. This area, 250 km^2 will ultimately transform into a greenhouse landscape, where local renewable energy is provided through solar and wind, and geothermal heat where existing gas-boreholes are connected to the energy and road network (both mitigating GHG-emissions), and where excess rainfall is captured and stored to use in the food-production process (mitigating drought and mitigating inland floods). The majority of this area is currently in use as poor agricultural grounds and will be made available, as ‘unplanned’ spaces, to transform when local actors take initiatives;

- Between the capital, Groningen and the Eems-Dollard area in the east, the most important waterways, transportation- and energy networks come together. Some of the most connected nodes are found here. For this reason a bio-based Green Heart is proposed The zone consists of a water-rich area for residential development (water storage, mitigation of inland floods), a clean technology zone in the middle, where all material (food, biomass and waste) from the southern part is processed (producing energy, mitigating GHG-emissions; using clean water from stored excess rainwater) and an algae plant to the east, providing energy, clean water and allowing sea water inland hence mitigating floods from sea. Around the core area several ‘empty’ spaces (with question marks, see Fig. 9.8) are projected. Currently in use as agriculture, they are classified as ‘unplanned’ and reservations, where further growth of the Green Heart might take place.

In addition to these areas, specific landscapes are reserved for nature (in the east) and food resources (north), being the Space for Resources-layer or for emerging occupation patterns (fifth layer) in urban centres and historic cores in the landscape.

The performance of the design is calculated for the energy supply, food production and adaptation measures (Roggema and Boneschansker 2010). Assuming an energy-saving performance of 50 %, the design provides enough locally produced renewable energy for the current population. The amount of food produced in the greenhouses is substantially more than demanded in the area, meaning food can be exported to other areas. Finally, there is enough space available to cater for adaptation measures, such as water storage, nature reserves, coastal defences and proclaim existing use in strategic locations as reservations for future adaptation uses.

9.6.1.3 Findings

When the two planning processes are compared several observations can be made:

- The processes differ in the sense that the regular planning process is linear, while the swarm planning process is designed to be iterative.
- Network analyses and identification of nodes in the swarm planning process, lead to new insights, different solutions and innovative propositions.

- The swarm planning process leads to increased attention for climate change and spatial integration of energy supply measures (mitigation) and strategies mitigating flood risks and dealing with droughts (adaptation).
- The swarm planning process has been carried out in a week, while the regular process lasted 2.5 years.
- The results of the swarm planning approach envisaged far greater change for the future than the regular planning process.
- The calculations illustrate that the swarm planning outcomes meet to a large extent the expected demands to deal with climate change threats, more than for the regional plan can be proven.

9.6.2 The Peat Colonies

The Peat Colonies, located in two provinces in the northern part of the Netherlands inhabit a population of approximately 200,000 people (excluding Emmen, which inhabits 109,000 people) and its size is 800 km^2 (Rothengatter 2011). In governance terms the Peat Colonies are a conglomerate of several municipalities, two provinces and two water-boards. Changing precipitation patterns pose major climate threats to the area: longer droughts with higher temperatures during summer, and the amount of rainfall on rainy days increases as result of heavy rain (Alterra et al. 2008). Despite the fact that rainfall is more extreme in summer, the precipitation falls more are concentrated, leaving the rest of summer with longer periods of drought. Especially in the Peat Colonies, which is already a relative dry area, this causes problems with the water provision, i.e. for agriculture. Another effect of drier circumstances, in combination with higher temperatures and poor soil conditions is the ecological difficulties, particularly the adaptation to the shift of climate zones (Vos et al. 2006), and increasing sea area, such as in the case of the Peat Colonies. The Peat Colonies are a net emitter of GHG-gases, contributing to global warming. Major other problems in the area are the shrinking population, joblessness and an agriculture under pressure.

9.6.2.1 Agenda for the Peat Colonies

Process

Since 2002 the so-called Agenda for the Peat Colonies is operational. In this ‘Agenda’ nine municipalities, two provinces and two water-boards collaboratively execute the programme for the area. In the second area programme (Van Eerten et al. 2008) the seven binding themes as well as the individual projects are brought together. The Agenda functions as a spider in the web of governments, connecting the individual municipal dots with the broader perspective (Fig. 9.9). The process is, therefore, a network based one, in which individual projects function often as

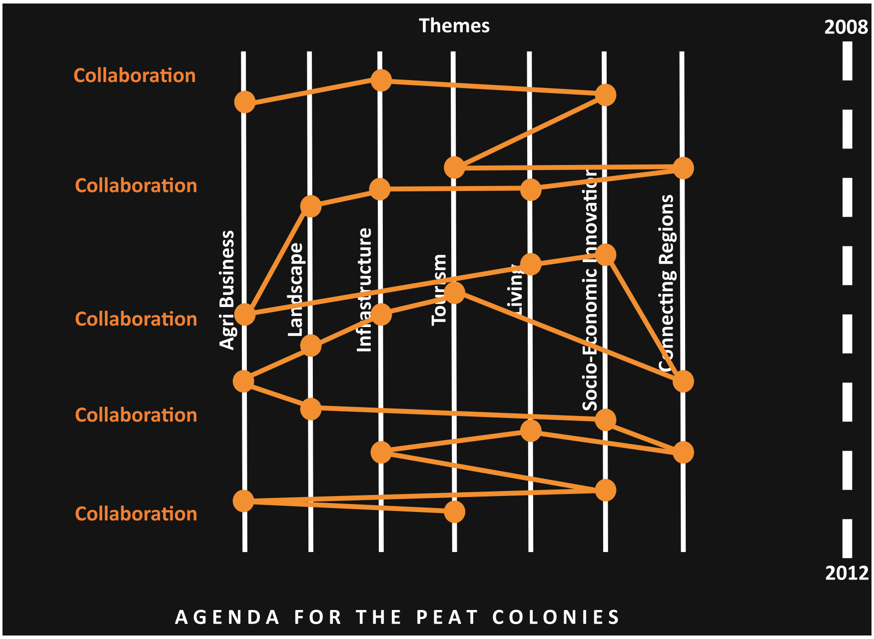

Fig. 9.9 Process agenda for the peat colonies

the platform for collaboration between parties. The main objectives for the Agenda are job creation and economic development, agribusiness, infrastructure, landscape and energy.

Content

The individual projects, each resorting under one of the seven main themes (Van Eerten et al. 2008) determine the content of the Agenda. Significant emphasis is placed on supporting the agricultural sector, as it is the most important employer and spatial function in the area. Several projects are performed to increase the capacity of the landscape to anticipate future climate change, such as creating space for water and realising an ecological corridor. Other major projects focus on improving infrastructure, the residential function and stimulating tourism.

9.6.2.2 Net Carbon-Capture Landscape

Process

One of the projects of the Agenda is the Hotspot Peat Colonies. This aims to design a regional plan, which functions as a carbon sink and integrates mitigation and adaptation strategies. The planning process is designed as an extended design charrette.

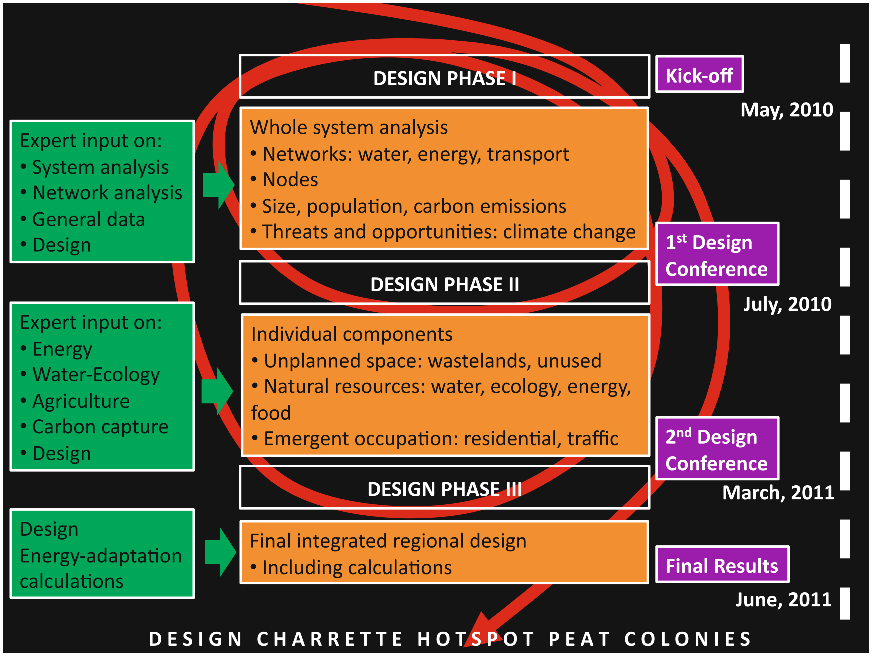

Fig. 9.10 Process Hotspot peat colonies

After the launch, the process consisted of two design conferences and presentation of the final results (Fig. 9.10). In the first phase the water, transport and energy networks are analysed and the most connected nodes are identified. General data on economic value, landscape patterns, population and carbon emissions were used to design, where connectedness is highest, the strategic interventions at the whole system level. In the second phase, these outcomes were used to detail individual elements of the energy-, water-, agricultural and ecological system. In the final phase the results from phases I and II are used to design integrated scenarios for a climate adaptive and carbon negative future. This iterative process involved experts in the fields of energy, ecology, water, living, mobility and policymakers from different layers of government, as well as responsible councilors, aldermen and governors in all phases of the design charrette.

Content

Besides the general data, the first design phase focuses on the network analysis. The key nodes for the water-, energy- end transport network were identified that are potentially suitable to start the emergence of a climate adaptive or climate mitigation development (Roggema and Stremke 2012). The water network is a fine-grained and intense network of bigger and smaller artificial canals, which were used to distribute peat. The dense energy network consists of the electricity

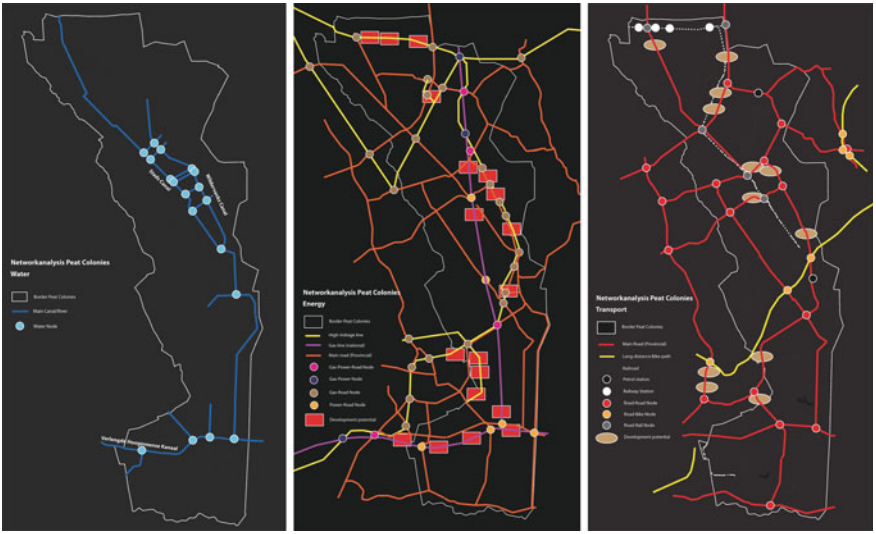

Fig. 9.11 Key nodes in the water, energy and traffic network

and natural gas distribution grid. The transport network, especially the major and minor roads, is also very intense. In these elaborations two different nodes are found (Fig. 9.11). Nodes that are crossings of individual infrastructural elements, such as crossing roads and railways, waterways or gas and electrical grids and nodes that emerge because networks touch on existing urban areas. Both types are highly connected and likely to perform growth or future developments. Overlaying these analyses brings about the highest connectedness and subsequently the central nodes to invest in future developments, such as renewable energy systems or adaptation measures, where the interconnectedness once more exacerbates the richness.

These nodes are considered in two fundamentally different ways, leading to two designs:

- They are the starting-points of centrally organised production units, which produce and export clean water, food and energy, but also are the core areas of water storage and ecology: Peatropolis.
- They are decentralised cores, encapsulating small-scale and self-sufficient entities in the landscape, which provide themselves autonomously with energy, material, water and food, becoming ‘resource-neutral’: Lonelycolony.

Both designs are spatially visualised in Fig. 9.12 (Broersma et al. 2011).

The Peatropolis design takes a centralised approach to address the climate threats (excess rainfall, droughts, ecological degradation and GHG-emissions) in an integrated way, focusing on harvesting rainwater, creating a robust ecological structure and using renewable resources for the energy supply. The networks and

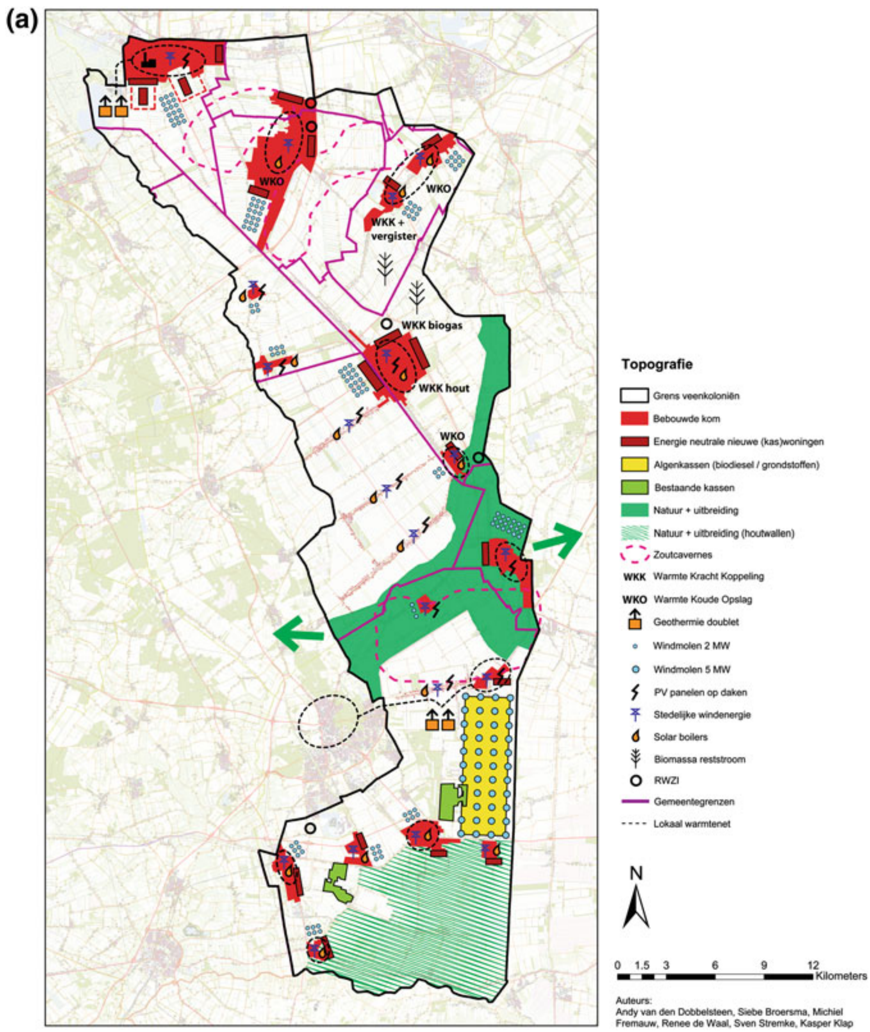

Fig. 9.12 Two spatial models for the net carbon capture landscape. **a** Lonely Colony. **b** Peatropolis (Broersma et al. 2011)

core nodes of water, energy and transport determine the design. In the central water spine (the 'Stadskanaal') and its ramifications excess rainwater is harvested (mitigating inland flooding and preventing drought impacts). This water is delivered to the central production units, the greenhouses, where large-scale algae breeding (delivering bio-diesel, clean water) occurs and food is produced. These greenhouses are positioned between the side streams of the main water system. At the end of these side streams, new nodes and hubs are introduced where the

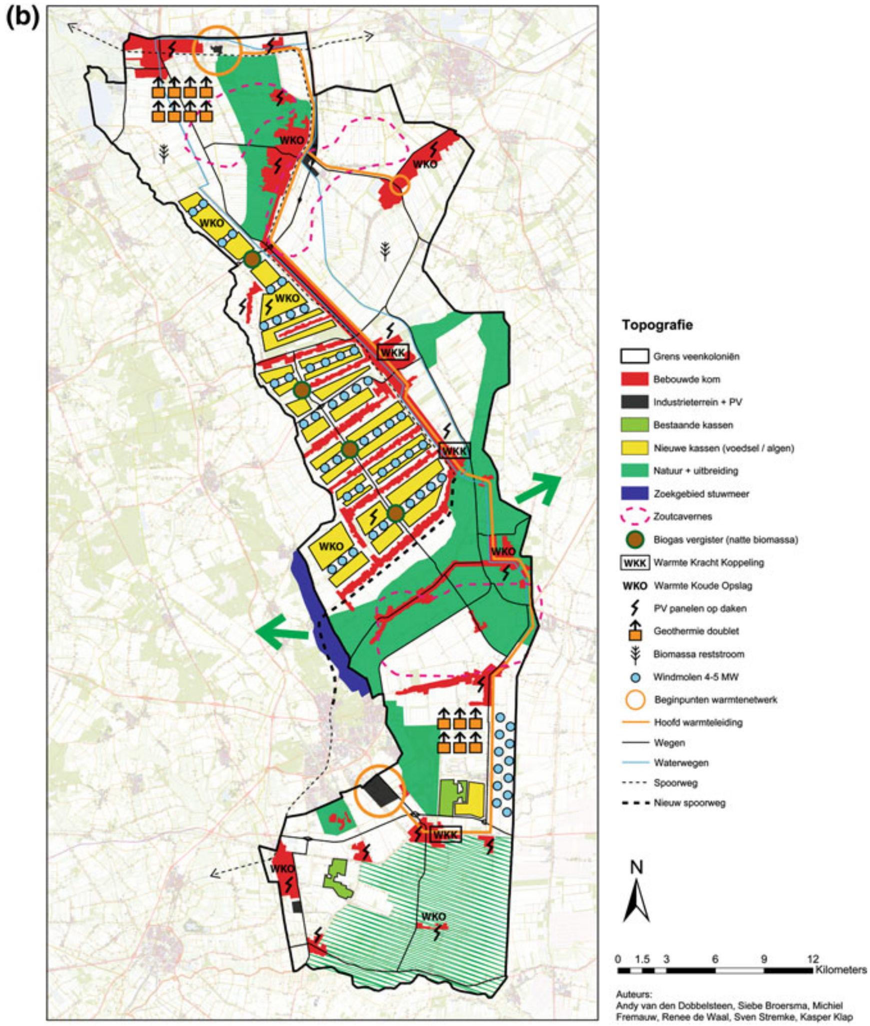

Fig. 9.12 continued

products from the greenhouses (energy, water, food) connect and exchange with the central spine. At several places the major networks connect with the surrounding areas in order to make further distribution possible. The major water spine forms also the basis for creating extended forest and a robust ecological structure (upgrading ecological quality and biomass production). Between the greenhouses large wind-turbines, in combination with semi-transparent PV-foil, produce a large amount of electricity, mitigating, together with delivery of waste- and geothermal heat to residences, GHG-emissions. Because of the abundance of space in this part of the Netherlands the proposed structure of the central spine and side streams includes large flexibility to be adjusted when adjustments are necessary. Hence ‘unplanned’ space is found within the structure, allowing sudden extreme rainfall events or necessary ecological extensions to host refugee species, to find space. Finally, it is highly likely that emerging occupation will occur where the innovative greenhouses are clustered with existing town centres and the water and transportation network.

The Lonelycolony design proposes local, autonomous entities to tackle the climate impacts. Isolated strong clusters are located in nodes with the highest connectedness, or where energy-, water- and transport networks come together. Each settlement becomes resource-neutral: it produces its own energy, food and clean water. The following measures are taken in each autonomous settlement:

- Harvesting excess rainwater in the vicinity of the cluster (mitigating drought and inland flood);
- Energy: industrial waste and geothermal heat supplied via underground networks, new houses to be energy neutral, existing stimulated to generate their own energy (solar, wind);
- Food production in local gardens and small-scale agriculture;
- Additional forests and nature, linked with the water network (supply biomass for bio-CHP’s) improve the ecological qualities locally.

Outside the core areas, households would need to provide for their own electricity and heat (PV, solar heating and small-scale wind-power). In these outside areas, the landscape is no longer in use as agricultural area, because all required products are provided from the individual settlements. Hence the space around the cores remains unidentified and can be occupied in times of climate hazards or when additional agricultural production capacity is required. In the coherent yet small village cores emerging occupation is most likely to occur.

For both scenarios, the calculations of the energy, food and adaptation performance have been conducted:

- Calculations found that both models have the potential to transform the Peat Colonies to an energy producing area, which at least can become Carbon Neutral.
- In both models the food supply is arranged for within the area; in the Peatropolis model food can be exported form the area, while the Lonelycolony is autonomous.
- In both models there is sufficient space available to implement adaptation measures. The proposal for Peatropolis offers more robust and structural space to realise adaptation measures, specifically for ecology. However, in the Lonelycolony model large unidentified spaces remain, which implicitly are left to become wastelands. Potentially, out of this new ecological dynamics will emerge.

9.6.2.3 Findings

Comparing the two planning processes several observations can be distinguished:

- The processes differ. The Agenda is a typical network. This process is chaotic due to the reliance on individual projects and demands determining the progress, which are often dependant on individual employees. The Hotspot process is iterative, involving a broad pallet of experts.
- The individual projects in the Agenda determine the outcomes. Infrastructure, education, job-creation or agribusiness projects will deliver the expected outcomes. The results in the Hotspot focus on the identification of system change, this encourages the tackling of problems associated with climate change.
- Network analyses and identification of nodes in the Hotspot process lead to new insights, different solutions and innovative propositions, such as algae-breeding in greenhouses.
- The Agenda process builds on collaboration between government and stakeholders. In the Hotspot process, experts and policymakers design together.
- In the Hotspot a larger change is foreseen as explicit triggers are placed on strategic points in the networks (greenhouses, core clusters).
- The Hotspot delivers spatial designs, while the Agenda puts more emphasis on the process and decision-making.

Table 9.2 Comparison between regular and swarm planning

		Regular planning	Swarm planning
Groningen	Process	• 2.5 year process	1 week
		• Public consultation	Expert involvement
		• Linear	Design charette
			Iterative
	Content	Allocation residential areas	Fully renewable
		Economic development	Mitigate climate change
		Infrastructure	Adaptation: water, ecology
		Landscape preservation	Mitigate flood risks (inland, sea)
		Energy saving	Prevention of drought impacts
		Limited aim of adaptation	Ecological development
			Food supply
Peat colonies	Process	4–10 years	1 year
		Collaboration	Expert collaboration
		Individual project orientation	Extended design charette
		Connecting dots/spider network	Iterative
	Content	Job creation	Autonomous settlements
		Youth education	Minimising GHG emissionsns
		Innovation in agriculture	Prevention of drought impacts
		Developing tourism	Harvesting excess rainfall
		New Infrastructure	Robust ecological structure
		Space for water	Local renewable energy supply
		Renewable energy	
		Energy reduction	

- The Hotspot calculations show that potential regional climate change threats can be dealt with. The outcomes of the Agenda could not be verified, which makes it more uncertain.

9.7 Discussion and Conclusions

When the ‘Obvious’ planning processes (Regional Plan, Agenda) are compared with the ‘Rethought’ processes (Increase, Hotspot) several differences can be observed (see Table 9.2):

- Responding in the obvious way—i.e. analysing the problem and ‘engineering’ the solutions—can mean repeating traditional solutions (e.g. a focus on economic, infrastructure themes) for new problems (e.g. climate change threats).
- Swarm planning processes are much quicker.
- The regular planning processes lack sufficient attention to climate threats, as their processes are focused on traditional planning aims (housing, economic development, mobility solutions).
- Regular planning processes formulate mitigation strategies (energy saving and the use of renewable resources).
- Swarm planning approach delivers spatial designs and future options, while in regular planning documents spatial designs are lacking. Regular planning focuses more on the process and decision-making.

The swarm planning approach offers an interesting opportunity to increase the adaptive capacity through spatial planning. The swarm planning approach consists of the following components (Figs. 9.13 and 9.14):

- The adaptive capacity of an area can be improved through spatial planning. The networks and the essential nodes are taken as the starting point of the design. Identification of the nodes with highest connectedness appoint the areas where

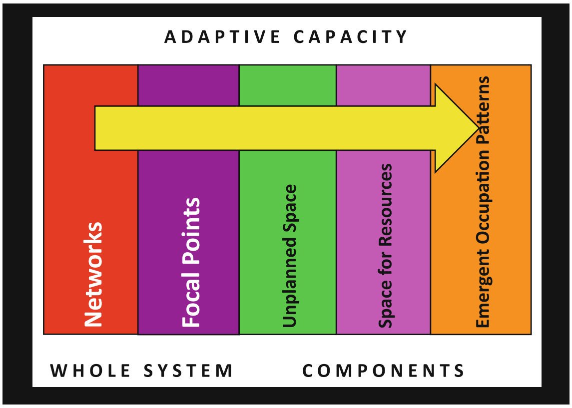

Fig. 9.13 Swarm planning approach as a linear process

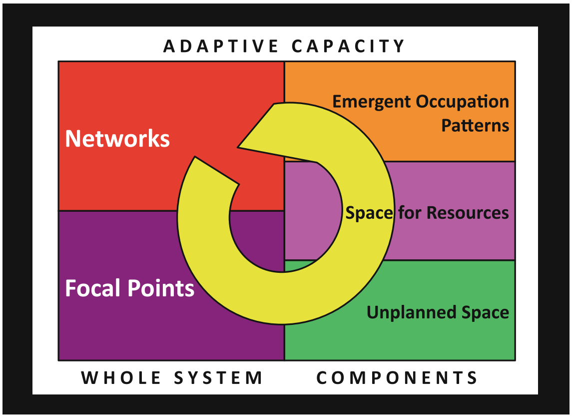

Fig. 9.14 Components of the swarm planning approach

dynamical circumstances are apparent, hence where it is most likely strategic directions are chosen. Applied to the climate change issue, when mitigation or adaptation strategies are executed here, they will have a serious impact on the system as a whole.

- It is expected that, once these nodes are identified, the rest of the elements in the system will orientate themselves and start behaving in the same direction.
- Therefore, the design of a climate proof region will need to start identifying these places.
- Subsequently, the choice for specific interventions, mitigating or adapting to climate change will fundamentally orientate the system, e.g. the area.
- When the adaptive capacity of the system is improved, the resilience of individual components is more likely to increase.
- On the level of individual components, the detailed design involving how and where specific measures are taken determines how adaptive or resilient the system becomes.
- The individual components consist of the elements belonging to the layers of the unplanned space, natural resources and emergent occupation.
- Elements belonging to the unplanned space layer are areas that are unidentified or not categorised in the planning document, or elements that perform a certain function but are expected to change function when necessary. Wastelands, abandoned areas, purposeful defined 'empty space (without a function)' or agricultural grounds, parking space or parks, all able to change function can be identified as 'unplanned'. The flexibility that these elements introduce allows the total system to change more easily and adapt to new circumstances.
- The elements of the resources layer generally are found in the ecological domain. Large nature reserves and forests, water basins and storage areas but also food production areas or grounds where energy is produced belong to this layer. These functions allow the area to become more independent from external suppliers, hence inherently becoming more resilient for external shocks.

- The elements of emergent occupation are naturally found in intensive (urban) areas. Where a mix of functions is apparent end interactions occur new connections are made and new patterns emerge.

These swarm planning components are not a step-by-step approach. In a planning context, a subsequent linear execution might work (as shown in Fig. 9.13), because every component poses specific questions for the design, however all the components need to be considered in an integrated manner, allowing for mutual exchange and enrichment (see Fig. 9.14). The success of the swarm planning approach in design charrettes depends upon an iterative and integrated approach.

The results of the swarm planning approach addressed climate aspects. However, these projects specifically aimed to create a climate resilient design in the first place. The question is whether swarm planning when used in a regular process will deliver plans better performing results for dealing with climate change. This is an interesting question and deserves further research.

The above question can be turned the other way around. When swarm planning is used in regular processes does it produce more resilient results for all other functions as well? Does it lead to plans that increase the resiliency of the economy, more resilient infrastructure or more resilient residential areas?

Finally, the swarm planning approach focuses on the opportunities of urban and landscape systems to deal with or even profit from climate change impacts. It does not formulate climate change as a complex and difficult problem. As a positive approach, it embraces strategies to support the mitigation or the adaptation of climate change; it aims to use climate impacts as a factor to improve the adaptive capacity of the landscape. Whilst creating liveable, sustainable and enjoyable environments, it leaves room for the unplanned and welcomes surprises, while giving direction and enabling all kinds of processes to emerge.

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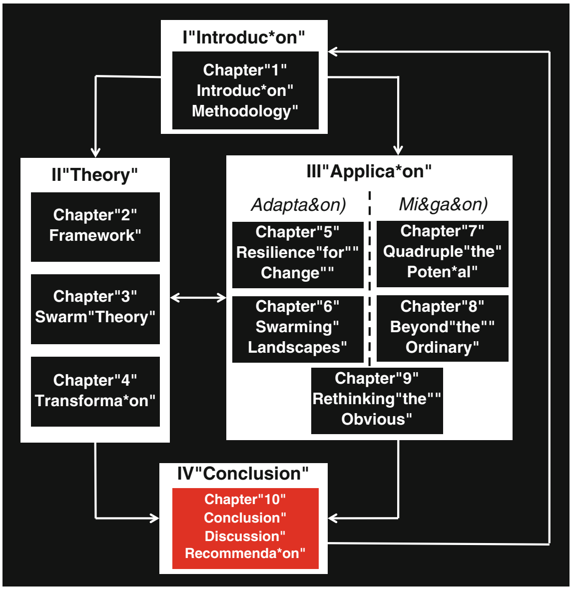
The Bridge: Nine–Ten



The research presented in chapters two to nine is concluded in this, final chapter. Not only are the research questions summarised and answered, the Swarm Planning Framework is explained it its components. Finally, the several pilot design that were presented over the course of the research are scored against the criteria for good adaptation planning in order to judge the usefulness of the Swarm Planning Framework.

Chapter 10
Conclusion, Discussion and Recommendations

10.1 Introduction

In this, final chapter the research is concluded. The two main parts of the research, answering Primary Research Question One and Two respectively, are discussed first. All results of the first part jointly shaped the theoretical basis for the Swarm Planning Framework, which is applied to several pilot designs in the second part. These designs are tested against the criteria as formulated in the introductory chapter. This concluding chapter ends with reflections on the research and recommendations.

10.2 Research Questions

The following two Primary Research Questions (PRQ's) are defined (see Chap. 1):

1. Can a spatial planning framework be developed that is capable to deal with the (wicked) characteristics of climate adaptation?
2. Does this alternative spatial panning framework produce designs for adaptive cities and landscapes?

These questions are subdivided in Secondary Research Questions (SRQ's), which have been the subject of the research presented in the subsequent chapters in this thesis. The results of every piece contributed to the development of the overall Swarm Planning Framework and the application in practical pilot designs for climate change

R. Roggema, *Swarm Planning*, Springer Theses, DOI: 10.1007/978-94-007-7152-9_10,

10.3 Primary Research Question One: Developing a Planning Framework

The first Primary Research Question (PRQ1), "Can a spatial planning framework be developed, which is capable to deal with the (wicked) characteristics of climate adaptation?" is subdivided in four secondary questions (A–D).

10.3.1 Research Question A

Secondary Research Question A reads as follows: "How can the 'adaptation gap', between tame spatial planning practice and the wicked character of climate adaptation be closed?" This question was subject of Chap. 2 (Towards a Spatial Planning Framework for Climate Adaptation). Properties that normally belong to Complex Adaptive Systems have been modified in this chapter in order to make them suitable for usage in a spatial planning context. From this exercise several processes, such as emergence, self-organisation, tipping points and fitness landscape (Fig. 10.1) are determined that could bridge the gap between spatial planning practice and climatic trends.

10.3.2 Research Question B

Secondary Research Question B reads as follows: "What kind of planning framework is capable of unifying the time gap, between short-term-oriented spatial planning and long-term-oriented climate adaptation?" This research question was also part of Chap. 2 and was answered through an adjustment of the existing Layer-Approach into Five Layers. Each of the five layers is capable of linking spatial elements with an identical time-rhythm, or the pace they tend to change. The five layers form an important basis for the Swarm Planning Framework (Fig. 10.2).

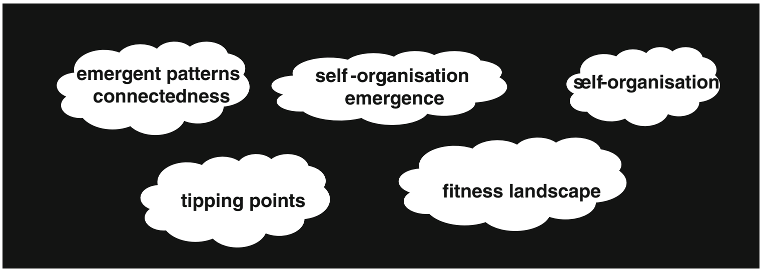


Fig. 10.1 Complex adaptive processes that could bridge the gap between climate and spatial planning

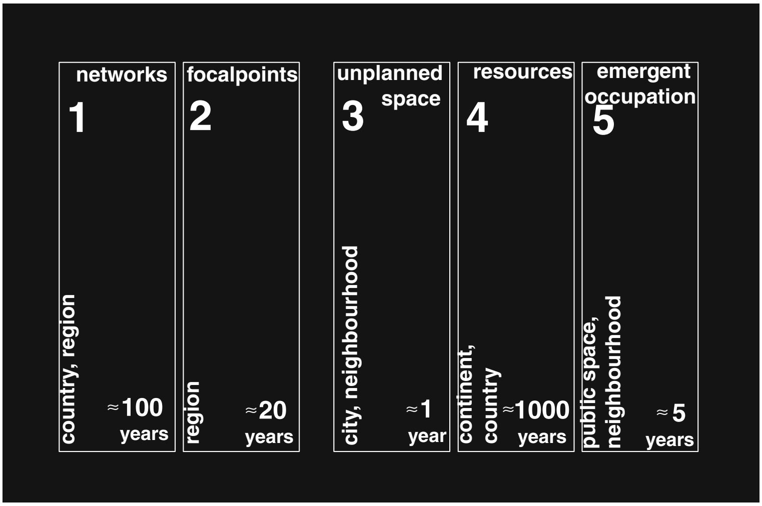


Fig. 10.2 The five layers that could jointly bridge the gap between long-term (climate) change and short-term planning

10.3.3 Research Question C

Secondary Research Question C reads as follows: "What is a suitable planning method/approach for dealing with wicked problems, such as climate adaptation?" This question was subject of Chap. 3. In this chapter the Swarm Planning Theory is explored. One of the basic concepts is that self-organisation takes place at two levels of complexity (dual complexity): the system as a whole and of its individual components (Portugali 2000). This allows the system to perform a higher adaptive capacity. The two levels of self-organisation form a basic element of the Swarm Planning Framework (Fig. 10.3).

10.3.4 Research Question D

Secondary Research Question D reads as follows: "What is the most suitable pathway to achieve a fundamental shift towards a spatial system, which is capable of increasing resilience?" This question was the subject of research in Chap. 4. The most suitable way to achieve a fundamental shift in spatial systems is through a transformation, which is to be started by looking for (spatial defined) B-minus elements, the announcers of a future, desired, system B, or through the creation of these B-minus points. These points are most likely found where networks are most intense and connected, e.g. where focal points are. In order to start and facilitate the ongoing transformation of the spatial system, free emergence and development in unplanned space needs to be possible (Fig. 10.4).

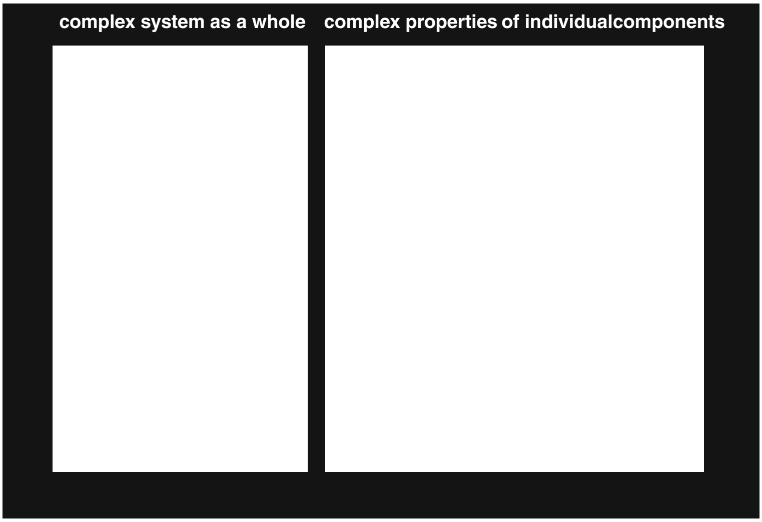
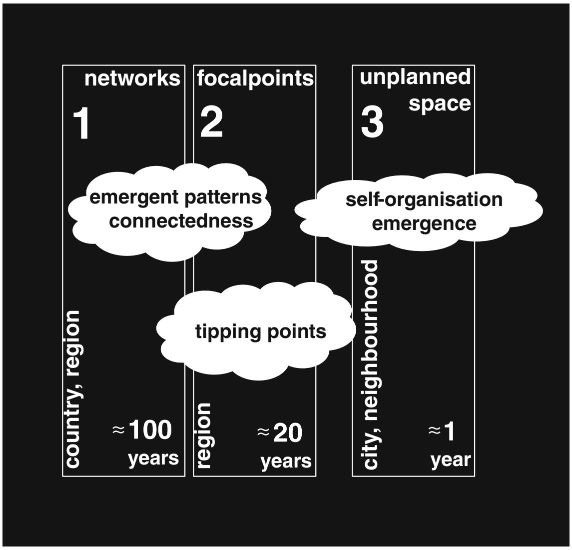


Fig. 10.3 Dual complexity, self-organisation at the level of the whole system and of its components

Fig. 10.4 The elements that play a crucial part in system change



10.3.5 Summary of the Findings PRQ1

These research questions and research outcomes have been discussed in Chaps. 2, 3 and 4. A summary of the results addressing the first primary research question is given in Table 10.1.

Table 10.1 Summary research results primary research question one, secondary research questions A-D

Primary research question one	Secondary research questions	CH	Results secondary research questions	Result primary research question
Can a spatial planning framework be developed, which is capable to deal with the (wicked) characteristics of climate adaptation?	A. How can the 'adaptation gap', between tame spatial planning practice and the wicked character of climate adaptation be closed?	Two	Describe spatial planning elements in a similar way as climate adaptation characteristics can be described, using the properties of complex adaptive systems (CAS)	Swarm Planning Framework, consisting of two levels of complexity and five layers of time dynamics
	B. What kind of planning framework is capable of unifying the time gap, between short-term oriented spatial planning and long-term oriented climate adaptation?	Two	Bring spatial planning elements together in one framework, which consists of different parts (layers) for each time dynamic/ horizon	
	C. What is a suitable planning method/ approach for dealing with wicked problems, such as climate adaptation?	Three	Swarm Planning Theory, which emphasises the self-organising capacity of systems as a whole (landscape, city), as well as their individual components	
	D. What is the most suitable pathway to achieve a fundamental shift towards a spatial system, which is capable of increasing resilience?	Four	The most suitable way to achieve a fundamental shift in spatial systems is through a transformation, which is to be started looking for (spatial defined) B-minus elements, the announcers of a future, desired, system B	

10.4 Primary Research Question Two: Application of the Planning Framework

The second primary research question (PRQ2), “does the alternative spatial planning framework produce designs for adaptive cities and landscapes?” is subdivided in four secondary questions (E–H). A range of pilot designs were developed and qualitatively tested according the following criteria:

1. Reduce social, physical and also spatial vulnerability to the impacts of climate change. Can the social system, the physical system and the spatial system adjust themselves or respond to a hazard or disaster? Are the spatial elements in the city or the landscape able to change if necessary? Is there space available in the city or landscape where social and physical systems can find the flexibility to change (expand, shrink)?
2. Reduce the likelihood of occurrence or magnitude of climate hazards and disasters. Does the design for the city-landscape contain protection and/or back-up structures and elements? Is the city, landscape capable of changing in a short period to (partly) another use?
3. Be flexible to react to evolving hazards, which might result from actual, expected and unprecedented climate change. Does the design for the city and landscape allow for the flexibility to fill up spaces with new uses under changing climate circumstances, even if they are unprecedented?
4. Contain and implement adaptation strategies. Are the identified adaptation strategies implemented in the design for the city and landscapes?

These criteria are used to estimate the adaptive capacity of the designed landscapes. In order to perform according these criteria the different designs explored the use of (parts of) the Swarm Planning Framework.

10.4.1 Research Question E

Secondary Research Question E reads as follows: “How can the resilience of a region be improved, in order to support this region to deal with climate change?” This question is the subject of both Chaps. 5 and 6.

In Chap. 5, the Groningen idea map was developed in order to enhance climate adaptation at the regional level. In the design a combination of scales and layers are integrated (Fig. 10.5). There is thorough attention for safeguarding natural resources, but at the same time interventions are proposed in places in networks that are of strategic importance.

In the idea-map Groningen (Roggema 2007) adaptation strategies were designed in an integrated way. Coastal defences, fresh-water supply, adaptive agriculture and nature reserves form the main pillars of the design. The design strategies together reduce the vulnerability of the landscape, because the design

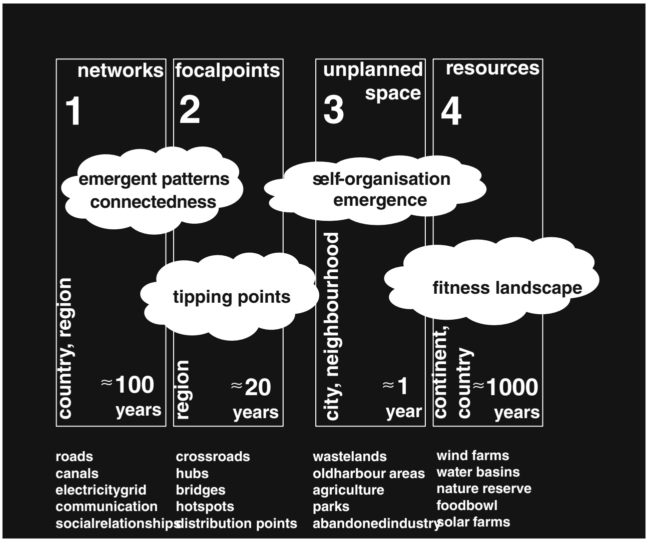


Fig. 10.5 Elements of the development of the climate adaptation idea map for Groningen province, positioned in the Swarm Planning Framework

pairs enhanced safety of the coastal defence with improved autonomous fresh water and food supply. Hazards are not prevented from happening through the design and the design measures do not reduce the magnitude of the hazards. However, the diversity of functions in the landscape, especially a richer and more resilient nature, together with secured water and food supply offers the potential to react to hazards, even if they come by surprise or are unprecedented. A diverse spectrum of adaptation strategies was designed, which can be implemented, however, depending on political decision-making.

A BAU scenario for the Groningen area is given through the most recent regional plan (Provincie Groningen 2009) and was analysed in Chap. 2. Its spatial flexibility is minimal and the plan does not reduce occurrence or magnitude of climate hazards. The plan provides some design measures, which reduce to a certain extent the vulnerability. When this business as usual development (resulting from current planning practice) is judged against the criteria and compared with the ‘Swarm Plan’ (Table 10.2) the Swarm Plan performs better (Roggema 2009).

The design for the Floodable Landscape was subject of Chap. 6. In the design for the Floodable Landscape the strategic intervention at a specific location is crucial as it determines how the intervention influences the unplanned space in the surroundings. The tipping point, emergence and self-organisation are key elements in the design (Fig. 10.6).

The design for the Floodable Landscape anticipates a potential flood through the introduction of inundated water in the landscape before an actual disaster happens. The main interventions in the design are the allowance of water over or through the dike, the building of housing on poles, floating or floodable and the

Table 10.2 Comparison of swarm plan and business as usual for the Groningen area

	Vulnerability	Occurrence and Magnitude of Hazards	Flexibility	Design & Implementation
Idea-map Groningen	Reduced, safe coastal defence, water and food supply	Not reduced	Increased flexibility: resilient nature, water and food supply	Strategies are designed and implemented
Business as Usual	Existing measures and policies	Not reduced	Not flexible	Some strategies and measures are designed
Legend:	Good	Neutral	Bad	

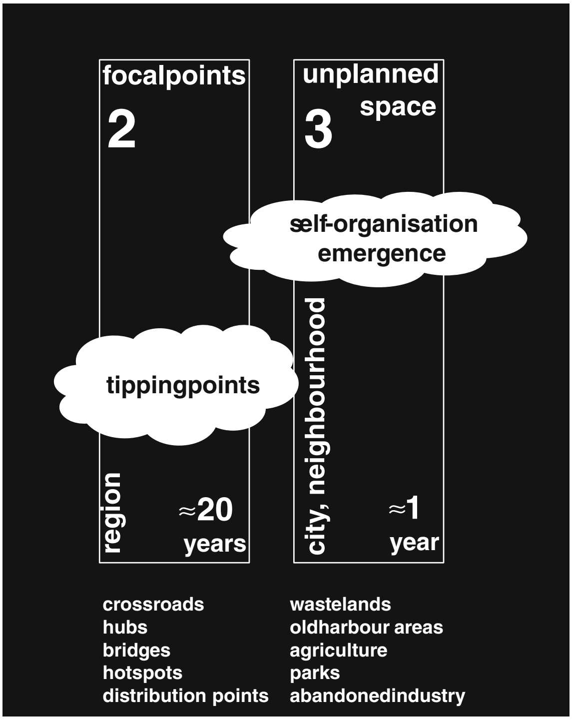


Fig. 10.6 The elements used in the Floodable Landscape positioned in the Swarm Planning Framework

positioning of housing in landscapes at a critical 90 cm above current sea level. The design provides a reduction in vulnerability through the anticipation of the hazard, which allows inhabitants to prepare well in advance. Although storm surge and higher sea water levels causing a possible flood are not changed, the water does not cause a hazard, because the landscape and the people are prepared for eventual seawater in their environment. Even if the hazard may take shape unexpectedly, the design is prepared for this unexpected. Higher sea levels than expected will not cause a disaster as the population and buildings anticipate eventual higher water. The adaptation strategies are designed and can be implemented, however, depending political decision-making.

Table 10.3 Comparison of swarm plan and business as usual for the eemsdelta/floodable landscape area

	Vulnerability	Occurrence and Magnitude of Hazards	Flexibility	Design & Implementation
Floodable landscape	Reduced vulnerability, anticipate the hazard	Both occurrence and magnitude are reduced	Landscape and people can deal with unexpected hazard	Strategies designed and implemented
Business as Usual	Vulnerability is reduced as result of dike strengthening	Not reduced	Not flexible	Only one strategy is designed (strengthening dike)
Legend:	Good	Neutral	Bad	

Current spatial policy for the Eemsdelta focuses on the economic development of the Eems Harbour. Climate adaptation measures are predominantly oriented on dealing with eventual storm surges in combination with a rising sea level. The proposal consists mainly on increasing the strength of the dike. This results in reducing the vulnerability to a certain extent. However, designing for climate adaptation is limited to one measure (the stronger dike) and this does not improve the flexibility. Moreover, it does not reduce the occurrence nor does it decrease the magnitude of climate hazards. The comparison with the design for the Floodable Landscape evidentially illustrates the advantages of the latter (Table 10.3).

Both example designs illustrate that a resilient future can be enhanced through the definition of crucial spatial elements, which allow for emergent processes to start in the landscape. This results in better adaptation to and mitigation of climate change.

10.4.2 Research Question F

Secondary Research Question F reads as follows: "How can spatial design be informed to reach higher mitigation goals?" The question is subject in Chap. 7. The local renewable energy potentials are found through the Energy Potential Mapping on several scales: supra-regional, regional, local and building. The arrangement of the right resources, supplying the demand on the different scales, provides enough sustainably produced energy to meet demand. The spatial arrangement gives directions for where, what and how productive functions are located. The example designs illustrate the role spatial design can play in (1) providing sustainable energy and (2) creating spatial quality in landscape and building (Fig. 10.7).

10.4.3 Research Question G

Secondary Research Question G reads as follows: "How can a full renewable energy supply be designed?" This research question is part of Chap. 8. In the

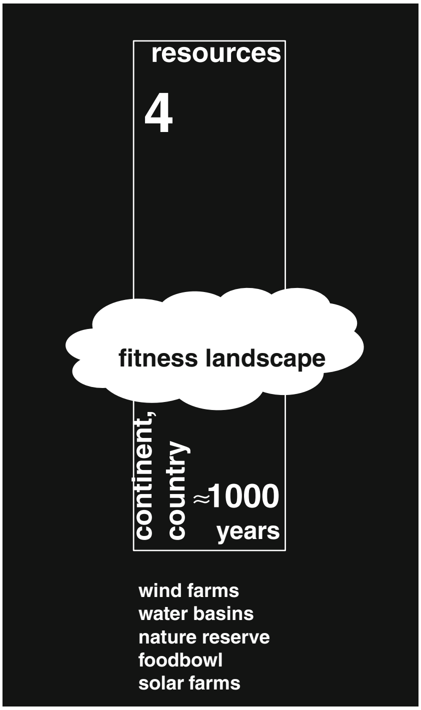


Fig. 10.7 Creating a fitness landscape for the supply of renewable energy focuses on the natural resources layer

design for a 'Zero-Fossil' region the resource layer is used to identify the local energy potentials (EPM) on which the design is based. Subsequently, the network and focal points layers are used to identify the locations where strategic interventions best can be realised in order to start a development in the area towards a fully renewable energy provision (Fig. 10.8).

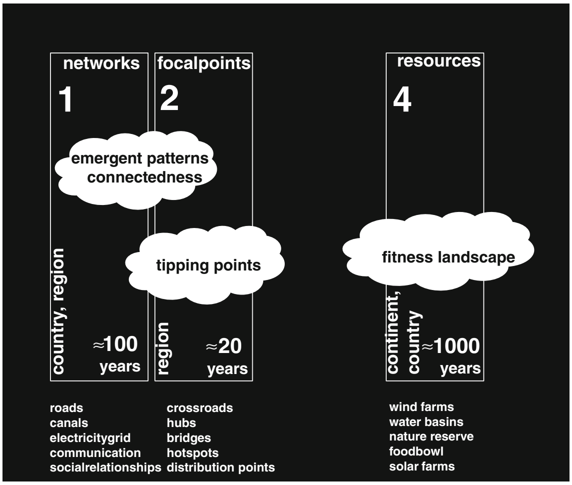


Fig. 10.8 The elements used in the design for the zero-fossil region placed in the Swarm Planning Framework

Table 10.4 Comparison of swarm plan and business as usual for the zero fossil region

	Vulnerability	Occurrence and Magnitude of Hazards	Flexibility	Design & Implementation
Zero-Fossil Region	Reduced through autonomous food and energy supply	Not reduced	Flexible through the availability of energy and food supply in case of disaster	Strategies are partly designed and implemented
Business as Usual	Unchanged	Not reduced	Not flexible	Only few adaptation measures are designed
Legend:	Good	Neutral	Bad	

The Increase II-design, the Zero-Fossil Landscape aims to provide the region with all the energy in a way that no fossil resources are used, nor imported (Roggema and Boneschansker 2010). Despite this focused aim, the design proposes also autonomy in the fields of food and water supply. The vulnerability in the landscape for climate change impacts is reduced through a combination of adaptation strategies. Nature and water system is made more robust and resilient, the food supply exceeds demand and the energy supply is based on a combination of all renewable resources available in the area. The design does not reduce the occurrence and magnitude of climate hazards. Through the autonomy of the food and energy supply the region becomes independent from other areas and is therefore better capable to provide support and supplies in case of a disaster. Adaptation strategies are partly designed and implemented, depending on political decision-making.

The BAU-scenario for this area consists of continuation of the current, mainly agricultural, land use. In this scenario few adaptation measures are designed or implemented for the area and these measures do not reduce vulnerability or increase flexibility and occurrence and magnitude of climate hazard are not influenced. Comparison with the design for the Zero-Fossil Region (Table 10.4) shows that the Zero-Fossil design scores better on three of the four criteria.

10.4.4 Research Question H

Secondary Research Question H reads as follows: "How can the Swarm Planning Theory be applied to the design of climate adaptive plans?" This question is subject of Chap. 9. In two designs for the Peat Colonies the networks are taken as the starting point for the design. Interventions are proposed and identified both on the system level (the crucial central nodes) as for individual components, such as specific elements in the water or energy system. These interventions suppose to enhance self-organisation and the adaptive capacity of the area, which as a whole supplies the system with renewable energy and water resources.

The two scenarios for an energy supply strategy, which captures more carbon than it emits, Lonelycolony and Peatropolis (Broersma et al. 2011) each design a

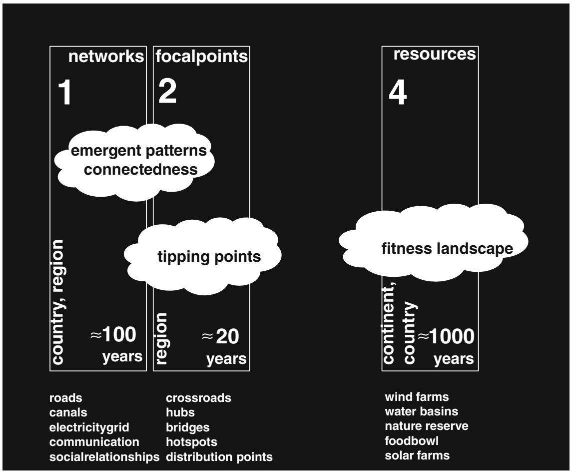


Fig. 10.9 The key elements in the two models for the Peat Colonies positioned in the Swarm Planning Framework

landscape in which the energy supply, in combination with systemic proposals, has become independent from other regions. In the sense that both models provide the energy required in the region (and beyond), they reduce the vulnerability of the region, although not in dealing with a disaster. The occurrence and magnitude of hazards is not reduced through implementation of the design strategies. When the hazard is energy-related (sudden shortage of energy for instance), the flexibility of the region is improved, but in other cases (floods, droughts) the flexibility is decreased. Adaptation strategies are to a certain extent designed and implemented in the scenarios (Fig. 10.9).

The Business as Usual policies for the Peat Colony area is covered in the regional plan for the Province of Groningen (Provincie Groningen 2009). This spatial policy is oriented on the consolidation of existing land-use, mainly agriculture. The consequence of this is that the BAU-scenario is not reducing the vulnerability, does not reduce the occurrence or magnitude of climate hazards and is not encouraging flexibility. Only few adaptation measures are proposed in the prevailing regional plan. Comparison learns that the Lonelycolony and Peatropolis scenarios, whilst performing not extremely good, still score better on three criteria (Table 10.5).

Table 10.5 Comparison of swarm plan and business as usual for the peat colonies

	Vulnerability	Occurrence and Magnitude of Hazards	Flexibility	Design & Implementation
Lonelycolony Peatropolis	Vulnerability to deal with energy shortages is reduce d	Not reduced	Flexible to deal with unexpected energy disaster	To a certain extent
Business as Usual	Is not reducing vulnerability	Not reduced	Not flexible	Only few adaptation measures are designed
Legend:	Good	Neutral	Bad	

10.4.5 Additional analysis: The Bendigo Design

In Chap. 3 the design for a bushfire resilient Bendigo is used as an example that illustrates the Swarm Planning Theory. Despite the design for Bendigo (Newman et al. 2011) does not directly address a research question, it adds to the use and testing of the Swarm Planning Framework. The design identified focal points and surrounding unplanned space in directing future urban development. It introduces specific spatial interventions, which trigger the emergence of occupation patterns(Fig. 10.10).

The design for a bushfire-resilient landscape in Bendigo aims to identify design measures that can be implemented over a range of time, whenever the bushfire hazard demands for it. A design intervention is proposed, which protects an area against bushfires and seduces people to develop a living environment here rather than in more vulnerable areas. The vulnerability in this design was reduced through the design interventions, allowing people to choose their preferential living environment. The occurrence of the hazard cannot be prevented, but through the preventive measures the magnitude of the disaster can be reduced. The design itself is flexible, e.g. new interventions are added when demand for new living areas or the fire hazard increases. The adaptation strategies are designed and can be implemented, depending on political decision-making

The BAU-policy for the Bendigo area is given by two elements: the Residential Strategy of the City of Greater Bendigo (Parsons Brinckerhoff 2004) and the findings of the 2009 Bushfire Royal Commission (Victorian Bushfire Royal Commission 2009). In the Residential Strategy there is no specific consideration given to climate adaptation measures and the findings of the Royal Commission mainly focus on the individual contributions to increase safety around the house and the voluntary buy back strategy. The proposed measures decrease the

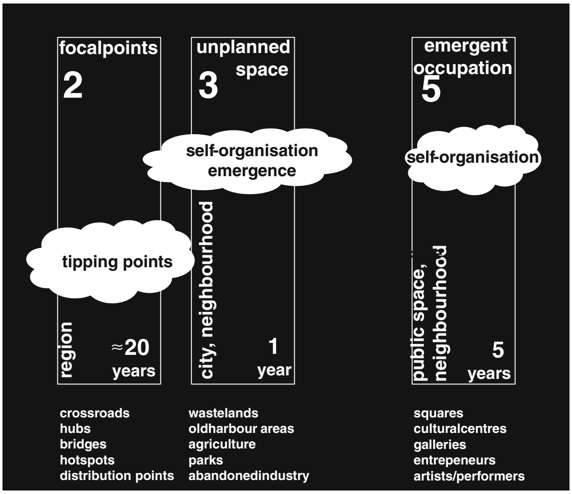


Fig. 10.10 The elements that formed the drivers for the Bendigo design, positioned in the Swarm Planning Framework

Table 10.6 Comparison of swarm plan and business as usual for the Bendigo area

	Vulnerability	Occurrence and Magnitude of Hazards	Flexibility	Design & Implementation
Bendigo	Vulnerability is reduced through anticipative interventions	Magnitude can be locally reduced	New interventions can be added is required	Strategies are designed and can be implemented
Business as Usual	Reduction of the vulnerability to a certain extent	Not reduced	Not flexible	Majority of measures from the Royal Commission are not spatial
Legend:	Good	Neutral	Bad	

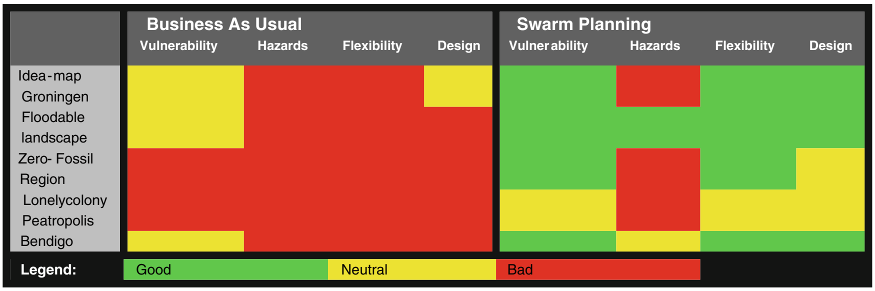
vulnerability to a certain extent, but the magnitude/occurrence of climate hazards is not reduced and the flexibility is not improved. The proposed design measures are in majority not spatial (Royal Commission) or not oriented on climate adaptation (residential strategy). Hence, comparing the Swarm Plan with the Business as Usual scenario shows a better performance of the swarm design (Table 10.6).

10.4.6 BAU and Swarm Compared

When all the results of the comparison between BAU-scenarios and Swarm Plans are included in one table (Table 10.7), the Swarm Planning designs score better on all of the identified criteria. Because these criteria were specifically designed to qualify the level of adaptation of spatial plans and the Swarm Planning Framework aims to support the design of climate adaptive plans, the outcome is not surprising.

This analysis illustrates that the use of the Swarm Planning Framework, which puts specific emphasis on the complex character of climate adaptation, provides better results than without the use of the framework. However, a couple of remarks can be made:

Table 10.7 Comparison between BAU scenarios (*left*) and results of swarm planning (*right*)



First, the most difficult criterion to be met in both cases (the BAU scenario as well as the Swarm Plans) is the influence the design has on the occurrence and/or magnitude of a climate hazard. One of the reasons for this is the scale at which the designs have been conducted. In several occasions the scale of the climate hazard alights the scale of the design.

Second, the flexibility criterion shows the largest difference between BAU-scenarios and Swarm Planning. This is caused by the fact that in the BAU scenarios the majority of the land-use is a given and remains unchanged or is limited to a single function. The Swarm Planning designs are more flexible, allowing land-use to change over time

When looking at the proposed design measures in the BAU-scenarios, there are only few adaptation design measures included. This is, logically, in contrast with the design derived through the Swarm Planning Framework, as these are specifically 'adaptation-targeted' designs.

In the fourth place, the reduction of the vulnerability differs gradually between the BAU scenarios and the Swarm Plans. In the BAU scenarios the existing situation is taken as the starting point for small, incremental changes. In general, the Swarm Planning designs for all pilot areas show better results in decreasing vulnerability than the BAU scenarios could, because these pilot design aim specifically to increase the adaptive capacity, hence reducing vulnerability

Finally, one remark regarding the designs for renewable energy landscapes is that these seem to score lower than the designs that aim to meet adaptation goals. A specific focus on a sustainable energy supply might therefore lightly contradict with the aim to design a landscape that meets the climate adaptation criteria. The reason for this is unclear. One of the reasons might be that the choice for a certain design intervention in the energy system fixes the space to stay flexible in future choices to change land-use when required from an adaptation point of view. Another explanation might be that the focus on the energy system and its technological requirements and orientation tends to create a successful energy supply system in itself, but it might be seen as operating footloose and as a stand-alone feature, without taking into account or giving attention to other functions, land-uses and unexpected change. It can be seen as a challenge to designs for renewable energy landscapes, climate adaptation designs and BAU-designs.

10.4.7 Summary of the Findings PRQ2

The results of the research conducted to elaborate the second primary research question are summarised in Table 10.8

Table 10.8 Summary of results regarding primary research question two

Primary research question two (PRQ2)	Secondary research questions (SRQ's)	CH	Results secondary research questions (RSRQ's)	Result primary research question (RPRQ)
Does an alternative spatial panning framework produce designs for adaptive cities and landscapes?	E. How can the resilience of a region be improved, in order to support this region to deal with climate change?	Five	Through the introduction of strategic interventions, which are capable to start a development in the region towards better adapting to and mitigating of climate change	In many of the pilot designs that were designed with the Swarm Planning Framework, the designs perform as examples of good climate adaptation
		Six	Through creating a common view, define adaptive elements as spatial elements and start the process of resilience through a strategic intervention	
	F. How can spatial design be informed to reach higher mitigation goals?	Seven	(Much) Higher goals can be reached through the analysis of local/regional renewable energy potentials and use this knowledge to base the design of houses, neighbourhoods and regions on	
	G. How can a full renewable energy supply be designed?	Eight	Use EPM as the basic analytical tool, base on these analyses a conceptual 'zero-fossil' design and determine the strategic interventions where the transformation will start (Swarm Planning)	
	H. How can the Swarm Planning Theory be applied to the design of climate adaptive plans?	Nine	The use of the five layers identifies interventions at system level and the individual components to increase self-organisation and their adaptive capacity	

10.5 Swarm Planning Framework

Derived from the research parts as described above, the Swarm Planning Framework (Fig. 10.11) is integrated into one image. This Swarm Planning Framework enables a spatial system to reach higher adaptive capacity and the spatial system is better capable to adapt to new, unforeseen and uncertain circumstances or environments. Climate change is such an external uncertain environment. Thus, if the adaptive capacity of the spatial system can be improved, the system will be better in dealing with climate change impacts. The components of the system need to be seen as complex adaptive entities, which together have the capability to self-organise and, by doing so, act as a whole system, developing (in times of crisis) towards higher adaptive capacity. Every component then needs to be attributed with adaptive properties; only then the components can play their role as complex adaptive entities. Moreover, every component is linked with a specific time rhythm, allowing similar dynamics self-organise in the same time dimension. In the entire system, all time rhythms (layers) are active at the same time, only change over different periods. Spatially, the components (or landscape elements) change according to their time rhythms, some faster, others slower, but they are localised where the faster and slower changes are accommodated (where it is possible). Fastest change is accommodated in the intense network nodes and where land-use remains 'unplanned'; slower are occupation and networks; slowest is the natural system/underground.

The key elements in the Swarm Planning Framework are: two levels of complexity, five layers, complex adaptive processes and ways to apply.

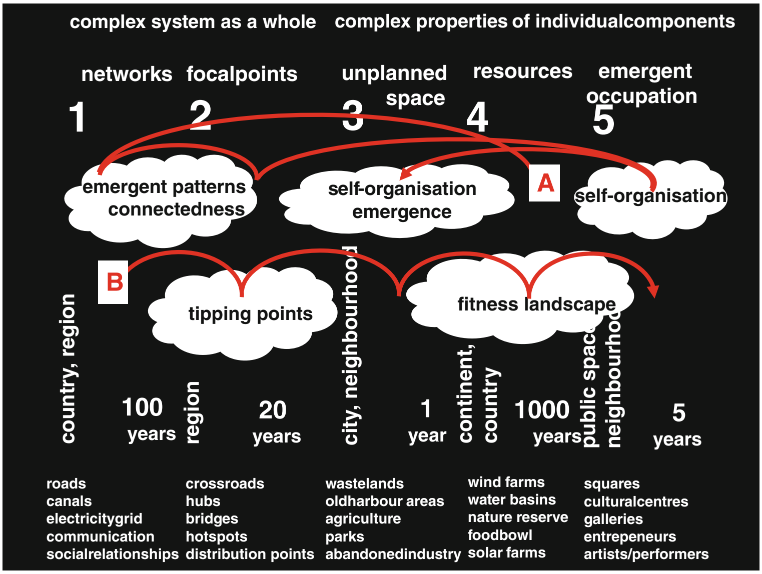


Fig. 10.11 Swarm Planning Framework

10.5.1 Two Levels of Complexity

Cities perform self-organisation at two levels of complexity. This dual complexity emphasises that the city as a whole operates as a complex adaptive system as do its individual components (Portugali 2000). This has been demonstrated for the city as a self-organising complex system, but it is likely to be valid at the landscape level as well (see Chap. 3).

10.5.2 Five Layers

The five distinguished layers (Roggema et al. 2012) (see Chap. 2) are linked to specific time horizons and are also connected to geographical entities. In each layer spatial elements with corresponding timeframes within which they tend to change, recycle or rebuild, are linked. The five layers together span the total required time dynamics: from very quick changing elements to the ones changing over very long periods. The first two layers, networks and focal points, focus mainly on the strategic intervention of the entire system, while layers three, four and five describe collective behaviour of individual components. Moreover, in Fig. 10.11 (not limitative) examples of specific landscape elements belonging to each layer are categorised.

Climatic trends, which are seen as developing over a long period and at larger scales are downscaled to dimensions that are closer to current development needs and the context institutions operate in, the preferred domain of spatial planning (Fig. 10.12). The Swarm Planning Framework fills up the gap between the

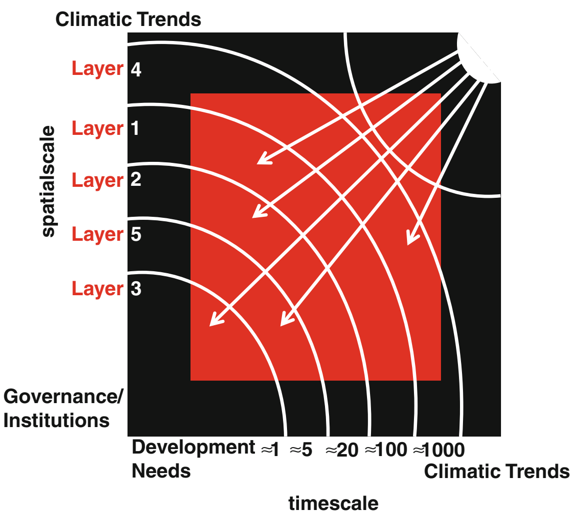


Fig. 10.12 Layers linking long-term climatic trends to several time horizons and spatial scales

'long-term-large scale' climatic trends and the short-term small scale of the majority of spatial planning practice.

The key facility to make this connection possible is found in the layer approach, which was developed to connect spatial elements of the same changeability to certain development or time rhythm. This makes it possible to assign specific (climatic) developments, such as instant flooding (layer three) or longer and slowly developing temperature rise (layer four or one) to a specific layer.

The layers of the networks (layer One) and of the focal points (layer Two) impact the functioning of the whole complex system, while the layers of unplanned space (layer Three), Resources (layer Four) and Occupation patterns (layer Five) primarily influence complex behaviour on the level of individual elements. All five layers are connected to specific time and spatial scales:

- Layer One (networks): Country-region, ≈100 year
- Layer Two (focal points): Region, ≈20 year
- Layer Three (unplanned space): City-Neighbourhood, ≈1 year
- Layer Four (resources): Country-Continent, ≈ 1000 year
- Layer Five (occupation patterns): Public Space-Neighbourhood, ≈ 5year.

10.5.3 Complex Adaptive Processes

The connection between climate adaptation, as a wicked problem, and complexity theory is established through the linkages of complex adaptive processes, such as emergence, self-organisation, the fitness landscape, connectedness and tipping points with spatial elements that belong to a certain (set of) layers. The following processes are distinguished in the framework:

- The networks and the focal points (layers one and two) can develop new patterns together, depending on the intensity of nodes and networks. The more intense the networks and nodes are, the higher the connectedness is and the more likely new patterns will emerge.
- Specifically for focal points (layer two) is the possibility to act as tipping points. Especially when these points are very intense, a certain combination of functions or events may prelude a system change. These points then are in hindsight the bifurcation point, where the direction and properties if the system changes.
- Processes of self-organisation and emergence are likely to happen when there is room for change and development. When the spatial configuration is fixed, it is not very likely to occur, but when space is unplanned (layer three) and accessible for spatial components (or agents), these self-organising processes are highly likely to occur.
- The concept of the fitness landscape is linked with natural resources layer (layer four) and with self-organising processes of layers three (unplanned space) and five (emergent occupation patterns). The layer of resources is determined by the long-lasting and hardly changing processes of soil forming, water- and ecological system change, which are seen as forming the basic conditions of the

landscape. Emerging processes in unplanned spaces or occupation patterns may force this solid system to the edge its stable state and when circumstances are right change to a new attractor: a new stable state. In this process (see Chap. 3) the system moves through the fitness landscape from one 'mountaintop' through a valley (of chaos, crisis) to a next mountaintop of stable, higher complexity and higher adaptive capacity.

- Where many and many different spatial elements, functions and people convene, it is highly likely that new configurations in the occupation patterns (layer five) emerge. The elements available self-organise into these new patterns. Often these places are also the focal points in networks.

10.5.4 Ways to Apply

The Swarm Planning Framework can be used in many ways. Two ways to apply the framework are distinguished here. These are represented through the red lines (as options A and B) in Fig. 10.11.

Option A is aligned according to the time and scale dimension of each layer. It starts from the long-term changes occurring at larger scales in the underground and natural resources (layer four). Once the existing qualities are identified the networks (layer one) and focal points (layer two) identify areas where new occupation patterns may emerge (layer five). This way to apply the framework ends with remaining unplanned space (layer three), which can be prevented from use until unforeseen developments require this space.

Option B is aligned according the dual complexities. It starts to identify elements that are capable of influencing the whole system. This is most likely to occur in the most intense nodes (focal points, layer two) in the network (layer one). Subsequently, around these nodes unplanned space (layer 3) needs to be designed in order to provide unrestricted emergence from these nodes. The networks, focal points and unplanned space form the basic condition for the remaining functions of natural resources (layer 4) and emergent occupation patterns (layer 5).

10.6 Discussion

The search for this framework started from the observation that current planning practice has difficulties in integrating climate adaptation. The developed framework offers a valid system to integrate climate adaptation, but in the context of this research the definition of the framework has been the main goal. This means that further elaboration is required to create a complete and detailed planning approach.

It has been demonstrated that building the framework and including complex systems attributions makes it possible to increase the role wicked problems can play in spatial planning. The main focus of this research has been to improve adaptation to climate change through spatial planning. However, what is valid for climate adaptation might also be useful for many other complex topics.

Challenge ahead of us lies in the elaboration of the theory, the practical use of the framework and the determination of complex adaptive properties to spatial landscape elements.

Over the research period a key theme emerged. The question how complex adaptive systems properties can be attributed to spatial planning and design originated in the beginning of the research and co-shaped the Swarm Planning Framework. However, how landscape elements perform complex systems behaviour in practice remains a question. How do landscape elements emerge, physically change over time, adjust and transform 'themselves' has been touched upon, but still remains a challenge for future research.

10.6.1 Limitations of the Framework

The Swarm Planning Framework aims to offer an approach that can be used in planning and design, and which includes complexity of problems that are not straightforward but wicked, such as climate change. Therefore this framework links complexity theory and Complex Adaptive Systems thinking with the fields of climate adaptation and spatial planning and design. The focus was to develop this framework and use it in several design pilots. Apart from a framework that supports the development of spatial adaptation planning and design, adaptation requires a spectrum of other aspects that are not addressed in the framework or in this research are required. Without being complete, the following aspects were not part of the development of the framework, but are required for good adaptation and/or ton increase the adaptive capacity:

1. Stakeholder involvement, community planning and advanced decision-making. The way key players in communities are involved in using the framework for climate adaptation planning is not investigated in this research. It is evident that the use of the framework is essential and success depends on the way key = players are involved and reach decisions;
2. Financial-economic analysis. The financial consequences the outcomes of a Swarm Planning process, compared with a regular planning process were no subject in the research. It is clear that further insights in these effects are worthwhile and might convince end-users to adopt the framework in their practice;
3. Deregulation and untighten planning procedures. The underlying aim of the framework is to create plans that can change and adapt to new circumstances over time. Existing regulations and strict planning procedures that currently exist often reduce the potential to change and adapt. This research underpins the need for untightening rules and procedures, but does not give solutions how to achieve this;

4. Design principles. The Swarm Planning Framework does not offer climate adaptation design principles, but it functions as a framework to work along. The designs derived from, sometimes only partially, use of the framework, showed that climate adaptive spatial designs can be developed. However, the development of general design principles of good adaptation for each of the layers in the framework could be added in order to increase the quality (e.g. adaptive capacity) of the resulting designs;
5. Modelling. The framework has been developed and several pilot designs have been produced, estimating that swarm behaviour will take place in each of the examples. However, these results have not been modelled. The modelling of landscape elements, attributing them with simple rules for (swarm) behaviour, subsequently identifying and executing a spatial intervention and finally capturing to which end-form or new stable state the landscape evolves to, could inform whether the intervention leads to a well adapted landscape.

10.6.2 Uses and Outcomes of the Framework

The framework allows many different solutions and outcomes. The designs presented in this research are functioning more as examples or illustrations to what results the fuse of the framework may lead, but they need not to be seen as a logic result from a step-by-step design process. When the user changes the design outcomes will be different as well.

Using the framework can also be viewed as a game-changer. It offers a different starting point of thinking. Instead of taking the established habit of how a spatial plan must be made, often leading to plans in which land-use is fixed or limited, the framework enhances, through application of dynamic and multiple time horizons in its different layers, designs, which lead to emergent networks, self-organising spatial concepts and evolving landscapes.

The framework can be used in different ways, as is illustrated in Fig. 10.10. The main difference lies in the sequence the layers are applied. One way of using the framework is starting from the large time and spatial scale and subsequently working through to the smallest time and spatial scales. This way probably comes closest to the current way of planning. Using it the other way around, e.g. starting from the small scale and working upwards, may also be possible. However, this contains the risk of being used mainly at the local scale and short-term, without looking into the wider context, which is important for sustainability issues and climate change. Another way of using the framework is starting with the first layer (networks) and then subsequently the others. Advantage of this approach is that it starts with layers (networks, focal points and unplanned space), which are in current planning not very well represented yet.

10.6.3 Weaknesses of the Framework

The framework undoubtedly has its weaknesses. First, it may be too open as it depends on gaining more knowledge and ideas over time, without immediate deciding on a certain aim. The framework as such does not include identification of a main objective, except the general aim to enhance climate adaptation. Perhaps it is wise to formulate several specific sustainability, climate adaptation or renewable energy objectives and integrate these in the framework.

By including these objectives in the framework might solve another weakness, namely the possibility to use the framework for another purpose, which might be conflicting with the aim to increase adaptive capacity and climate adaptation or even lead to mal-adaptation. One could imagine a spatial intervention, such as for instance creation of large, easy accessible car parks near shopping centres, touristic attractions or city centres, which enhance car- and energy use, leading to increase of global warming, requiring ultimately new or more adaptation. These links are not made very visible, and planning is conducted in an unconscious way, but the society created following this example can be perceived in large Australian and American cities. Mind the possibility to use the framework in a way that these interventions are planned in a conscious way.

Another potential weakness of the framework is that it becomes used for problems that are straightforward and tame. These type of problems need to be solved in a straightforward way. Usage of the framework makes solving these problems unnecessarily complex and time consuming.

The framework represents current thinking, as it is developed in a timeframe of concern about climate change and its accompanying complexity. Over time types of problems will change again and there might be demand for different frameworks in the future.

10.6.4 Reflection on Research Process

The way the research has been conducted ‘suffered’ and profited from the combination of being employed in academia and practice. On the one hand side the practical and political truth of immediate demands were a distraction from conducting the research. The political environment, in which several projects were embedded, is vulnerable for sudden change, depending on financial, political or policy preferences. It could happen that the colouring of a project changed during execution of the project. In a research constellation, one would prefer to keep the environment stable. On the other hand the position in practice offered access to projects and negotiations one normally wouldn’t encounter as a researcher. These insights, but also the results of projects enriched the research from the inside in a way that would not be possible coming as a researcher from outside. Being part of policymaking allows for development of research concepts that are both theoretical and practical and differs from a position observing policymaking 'in the making'. The backside of this dual position is that no matter how good the research plan is structured, changes occurring in practice interfere and sometimes dominate prioritising. In retrospective, this resulted in, one would probably say, ill-structured research. Again, this implies advantages as well as disadvantages. It might have led to a less rigorous research in progressing in a step-by-step manner, starting with the problem statement and hypothesis, through research questions, which subsequently are researched and concluded. An advantage in conducting the research in a more wicked way has been that unexpected research concepts could be harvested along the track. It made it possible to keep on searching for concepts instead of for data and it ultimately led to the development of the Swarm Planning concept and framework.

This kind of research, in which integrative thinking is profound and several scientific fields are assembled and aggregated, encounters some problems, as it is not possible to place it in a specific box. The consequence of this is that there is a lack of scientific discourse, or, the research is cross-cutting and did not gain the depth to fit in one of the discourses it can belong to. Linking climate change, spatial planning, complexity, transition thinking, socio-ecological systems and design has been the DNA of this research, but a slight change in the objective would have led to another DNA.

Perhaps, this kind of research is unique by definition, because each time it combines a specific set of scientific fields.

10.6.5 Final Recommendations

Finally, the offspring of this research lies in future research opportunities as well as in the application of the framework in practice. I would recommend the following:

1. The application of the Swarm Planning Framework in one or several councils or regional governments, offers two opportunities. First, the framework is applied to real-life problems and may lead to better adaptation and probably to adjustments of the framework for better usability in practice. Second, it forms an academic challenge to investigate the way the framework is used in practice and to what results this has led. Monitoring both of the experiences of local governments as well as the achieved results could form a substantial part of a future research agenda;
2. Further research is required about the way Swarm Planning can inform local community planning and decision-making. Adaptation is a process of planning at the local-regional level, where the impacts of climate change are felt and experienced. The Swarm Planning Framework might be of help to plan for this locally. The way planning processes are currently conducted is often experienced as top-down and sending knowledge instead of collaboration. The design of the planning process and decision-making requires further research, but it

would need to emphasise the ability and knowledge local communities own and the way these qualities can surface in the planning process. Additionally, Swarm Planning requires from government and politicians to have trust in the local self-organising capacity. For many subjects, climate change measures are perceived as negatively framed topics. Further research needs to be carried out about how these negative perceived topics can be framed in a positive way, focusing on the benefits for individuals;

3. The financial-economic benefits or drawbacks of the Swarm Planning Framework, compared with the more traditional frameworks, is a valuable research subject as it could convince councils and other investors in the public space to use the framework;
4. The Swarm Planning Framework has been tested in several pilot design at the landscape level. In general, space to move in the landscape setting seems to be larger than in the existing city. However, in the city the velocity of change is often faster than in the landscape. Additional research is required to apply the Swarm Planning Framework to urban environments and test whether this environment has more difficulties to adapt;
5. In the Dutch context every acre is in use and creation of unplanned space seems to be utopian. Further research needs to be carried out to explore the potential to create unplanned space in the Dutch situation. In essence the possible space that remains unplanned is space that can be used in case of a climate hazard. Without the availability of wastelands, double land-use or temporary land-use should be further explored;
6. Swarm Planning unifies a strong initial directive towards higher resilient landscapes with, the same time, loosening the regulative burden on emerging developments and initiatives. The latter requires that spatial land-use needs to be able to change easier over time than current land-use planning allows. The constraints of current regulations and planning procedures and the minimal necessary (de)regulation could deliver insights to what extent regulations are required. The question how a deregulated area functions and delivers higher adaptive capacity (or not) is a subject for further research;
7. The framework does not identify specific objectives nor does it identify certain preferable design principles that could help to realise these objectives. If the objective is to achieve a more sustainable future, in which energy is supplied using renewable resources and societies are prepared for potential future climate impacts, design principles need to be developed to support and achieve this. The development of these design principles needs to be part of a future research agenda;
8. Further research is required to gain insights how landscapes perform complex systems behaviour when a spatial intervention to enhance adaptive capacity is proposed. The landscape elements and their expected (swarm) behaviour need to be modelled and be used to understand the dynamic processes that will start taking place in the landscape. In this area, the knowledge and understanding, which has been built up in complexity and city research (Portugali 2000 and others) as well as the research and design carried out by Kas Oosterhuis on the

building level, as discussed in Chap. 3, can be harvested to use it for the landscape (Oosterhuis 2006, 2011);

9. The tension between spatial planning practice and the Swarm Planning Framework requires elaboration. Is current spatial planning focused on safeguarding vested interest and implicitly providing certainty through unchanged land-use, the Swarm Planning Framework urges land-use to change quicker. The question is how spatial planning practice can be enforced to shift from the search for certainty towards the creativity to anticipate future spatial requirements. The research should target to influence the creativity and courage of top management and politicians in all layers of government.

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