Towards a Landscape-based Regional Design Approach for Adaptive Transformation in Urbanizing Deltas

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DOI 10.7480/rius.6.94

Abstract

Deltaic areas are among the most promising regions in the world. Their strategic location and superior quality of their soils are core factors supporting both human development and the rise of these regions as global economic hubs. At the same time, however, deltas are extremely vulnerable to multiple threats from both climate change and the rush to urbanization. These include an increased flood risk combined with the resulting loss of ecological and social-cultural values. The urbanization of deltas can be understood as a set of complex social-ecological systems (and subsystems), each with its own dynamics and speed of change. To ensure a more sustainable future for these areas, spatial strategies are needed to strengthen resilience, i.e. help the systems to cope with their vulnerabilities as well as enhance their capacity to overcome natural and artificial threats. In this article we elaborate a landscape-based regional design approach for the adaptive urban transformation of urbanizing deltas, taking the Pearl River Delta as a case study. Based on an assessment of the dynamics of change regarding the transformational cycles of natural and urban landscape elements, eco-dynamic regional design strategies are explored to reveal greater opportunities for the exploitation of natural and social-cultural factors within the processes of urban development. Furthermore, adaptive transformational perspectives are identified to ensure reduced flood risk and inclusive socio-ecological design.

KEYWORDS

resilient urban planning and management, regional landscape design, water sensitive design, transformation perspective, adaptive urban planning, Pearl River Delta

1. Introduction

Urbanizing deltas are among the most promising and dynamic regions of the world.[1] As well as contributing greatly to the global economy, they are also valuable ecosystems (Meyer et al., 2016; Costanza et al., 1997). Deltas frequently accommodate large populations in particularly sensitive environments that are dominated by water systems. As a result, urbanizing deltas are extremely vulnerable to multiple threats (Nicholls & Cazenave, 2010; Ericson et al., 2006). Due to difficulties in steering the intensification of urban land use and economic activity within a sensitive water environment, compounding by the absence of effective governance, the outcomes of delta management are often a combination of ecosystem damage and the loss of socio-cultural values. This weakens the capacity of deltas to resist natural hazards as well as the risks associated with climate change, thereby negatively impacting the environment, the local economy as well as the health and prosperity of citizens that live around these water systems (Nijhuis, Sun & Lange, 2017).

Figure 1. The fast urbanization process within the PRD leads to confrontations between incremental long-term urban developments and fast short-term developments. Typical fishing villages and new urban developments in Pazhou, Guangzhou (photo: Guangyuan Xie, 2018).

Urbanizing deltas can be understood as a set of complex social-ecological systems and subsystems, each with their own dynamics and speed of change (Figure 1). To ensure a more sustainable future, spatial strategies are needed

1 This article is an adapted version of a Chinese language article simultaneously published in 风景园林 (Landscape Architecture) 170 (9); 8-22.

to strengthen resilience, assist systems to cope with their vulnerabilities, and strengthen their capacity to face natural and human-made threats. These strategies have to consider the complex interrelation of systems in order to avoid damaging ripple effects, such as when urban development increases the risk of flooding. Strategies like these can highlight the potential of ecologically-sensitive urban development that ensures economic and social growth, while also providing opportunities to strengthen natural systems and lower the risk of flooding (Nijhuis, Sun & Lange, 2017). At the same time, such spatial strategies must involve a wide range of social and economic actors, while also supporting the social, economic and cultural conditions of local people. These strategies should be communicated in persuasive ways in order to gain wide understanding, support and influence (Albrechts, 2011; Healey, 2006).

Of course, dedicated spatial strategies should not merely improve the living conditions within urban deltas but also promote adaptive measures to climate change in order to decrease the level of risk. Urban planning and management must display a certain degree of adaptive capacity in order to successfully create more resilient deltas. Strategies must also identify eco-dynamic design options that not only enable the integration of nature alongside urban development processes, but also implement adaptive design principles that ensure low flood risk. Additionally, it is necessary to integrate transformative processes in governance combining spatial planning, design and disaster management in order to optimize land-use, institutions and mechanisms for an efficient, sustainable and inclusive urbanization (Nijhuis, Sun & Lange, 2017).

From the 2000s onwards, there have been serious attempts to develop an adaptive-systems approach to the planning and designing of urbanizing deltas. Examples of such attempts include the Rhine-Meuse-Scheldt (RMS) Delta in the Netherlands (Meyer et al., 2015; Rhee, 2012), the Mississippi River Delta in the United States (Wagonner et al., 2014; Campanella, 2010) and the Mekong Delta in Vietnam (Marchand et al., 2014; Shannon & De Meulder, 2013). The current paper and related research suggest a much greater potential benefit in using urban landscape dynamics in territorial governance than more traditional planning strategies (Meyer & Nijhuis 2016, 2013; Van Veelen et al., 2015). In the following, we discuss a landscape-based regional design approach for the adaptive urban transformation of urbanizing deltas, taking the Pearl River Delta as an example, while also describing the approach in some detail. In so doing, we outline an integrative approach towards the planning and design of urban landscapes, whereby natural and urban dynamics determine both the pace and form of adaptation required for adaptive urban transformation (AUT) (Nijhuis, Sun & Lange, 2017).

AUT employs landscape-based regional design methods as an integrative and multi-scale design and planning approach. The aim is to steer urban-

rural transformative processes through a combination of sector activities towards more coordinated sustainable outcomes. Landscape-based regional design is considered to be an important strategy that shapes the physical form of regions using landscape as the basic condition to generate sustainable urbanized deltas (Nijhuis, 2019). It employs spatial planning and design to open up pathways to long-term sustainable urban landscape development. In summary, regional design is a transdisciplinary effort that not only safeguards sustainable and coherent development, but also guides and shapes changes that are brought about by socio-economic and environmental processes, while establishing local identity in a region through tangible relationships (Nijhuis, 2019).

2. Pearl River Delta

For the past four decades, the world's fastest developing delta has been the Pearl River Delta (PRD) in China. In 2014, it replaced Tokyo as the largest and most populated urbanized area on the planet (World Bank, 2015). Since the 1980s, the PRD has been at the vanguard of China's groundbreaking spatial planning and socio-economic thinking (Yeh & Li,1999). At the same time, the PRD now faces immense challenges regarding its long-term economic development because of threats posed by climate change and environmental degradation. These challenges include issues such as the disappearance of mangroves (Zhao, 2010), the loss of farmland (Hu & He, 2003), air and water pollution (Li et al., 2008), water shortages (Wang, Hu & Li, 2006), and a decrease in social security (H. Xiong, 2016).

On the one hand, the region is exposed to increasing flood risks due to urbanization in flood-prone areas (Figure 2) as well as rising sea levels and extreme typhoons/storms in summer, placing stress on the regions infrastructural systems. On the other hand, the deltaic ecosystem is becoming increasingly fragmented and vulnerable (Gao et al., 2012), resulting in a decline in both ecological services (Ye & Dong, 2010) and environmental carrying capacity (Huang, 2003). At the local level, large-scale interventions have replaced the historically diverse environmental and cultural heritage of the PRD with more uniform, featureless topographies (Guo & Situ, 2010). While local and national authorities are showing increasing awareness of the value of more integrated planning and design approaches, these have not yet been widely introduced (L. Xiong, 2016). For example, the implementation of the so-called national 'Sponge City' policy – a concept of integrated urban water management – has met with delays in the elaboration of both multiple and separate sectoral plans (Che, 2016).

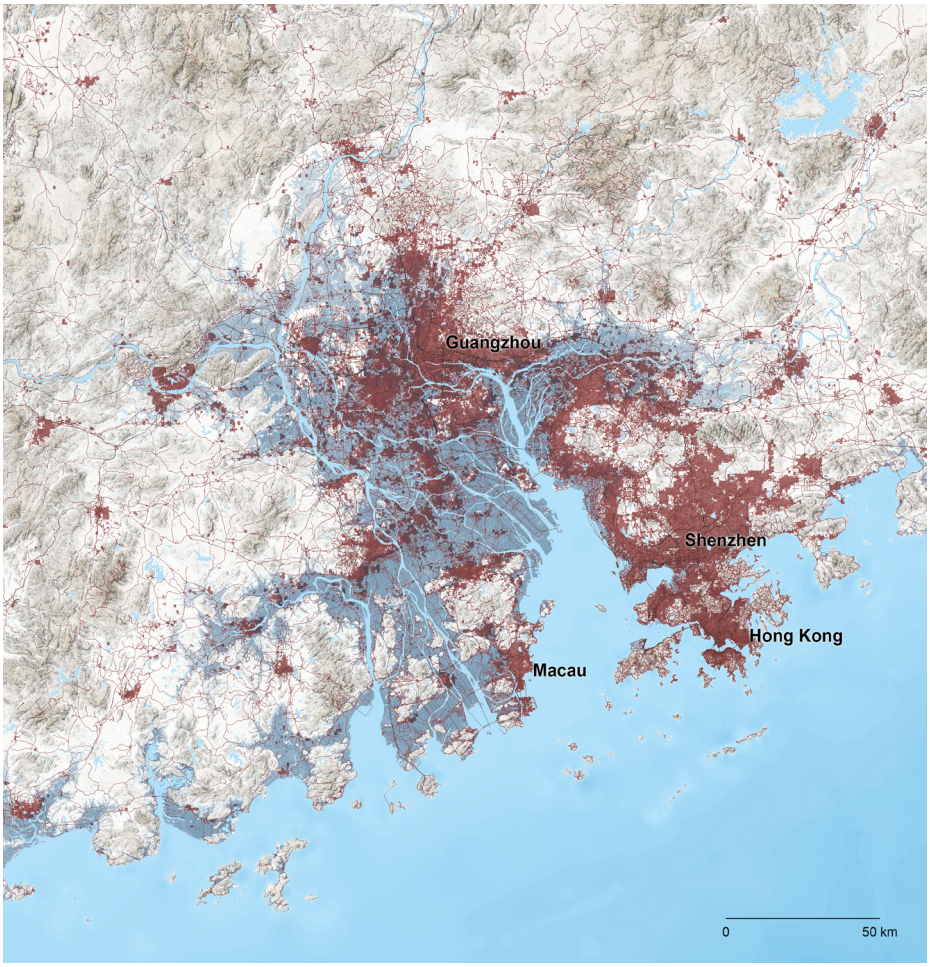

Figure 2. The PRD is the fastest urbanizing delta in the world. Most of the construction takes place in the flood-prone lowland (+10m zone, here indicated in dark blue), thereby increasing the flood risk (map: Steffen Nijhuis, 2018).

In order to guide the PRD towards a more sustainable future, there is an urgent need for new ways of planning and design in the practice of its urban development. The emerging concept and practice of landscape-based regional design offers a way of resolving the conflicts and threats that arise between economic development and environmental recovery, as well as reducing the negative repercussions of climate change. The high speed at which the PRD has developed makes it a particularly valuable case study to explore and test the potential of more adaptive integrated planning approaches, such as landscape-based regional design.

3. Landscape-based regional design

Landscape-based regional design aims to enhance spatial development by applying bioregional planning and design principles that view the urban landscape as an inclusive, dynamic and complex system. The approach builds on ideas developed and implemented by Charles Eliot (1893), Warren Manning (1913), Pieter Verhagen (1920), Patrick Abercrombie (1922), Fritz Schumacher (1923), Ian McHarg (1962) and Philip Lewis (1996).

Regional design applies principles from landscape architecture, landscape ecology, geography and architecture to spatially-oriented research, design and planning. It also utilizes ideas from systems thinking as well as complexity theory to promote a more comprehensive form of regional planning and design that addresses the complex web of relationships making up the urban landscape (Nijhuis & Jauslin, 2015). In this way, regional design offers a mode for urban transformation, the preservation of biodiversity, water resource management, improved leisure facilities, community building, stronger cultural identity and economic development (Neuman, 2000).

Landscape-based regional design identifies and guides development towards the most advantageous places, functions, scales and inter-relationships (*the strategy*) to ensure a region's sustainable growth while setting the scene for local initiatives (*interventions*) (Nijhuis & Jauslin, 2015). Regional design determines the physical shape of regions based on knowledge of the natural and urban landscape physiology and functioning with the objective of generating favourable conditions for future development. This approach also operates at different scales, from regional to local, as well as accommodating both general or more specific measures. In so doing it preserves overall continuity and promotes local contingency, also enabling a more uniform balancing of services and qualities between parts of a territory (Busquets & Correa, 2006).

Regional design is like an open-ended strategy aimed at protecting and developing resources. This is achieved by guiding developments and establishing future conditions for spatial development by means of landscape planning and design (Nijhuis & Jauslin, 2015). It also sets up robust and adaptive systems that are resilient and open to change. The organizational structures, i.e. 'strong' and coherent structures such as water and transport systems, provide the backbone for regional development; further, they facilitate adaptation to local circumstances, are strong enough to withstand challenges and yet sufficiently flexible to cope with future situations (Corner, 2004).

Regional design rooted in landscape is a social-inclusive approach that acknowledges the collective nature of the urban tissue and enables various 'actors' to participate (Allen, 1999). This approach to design generates a directed field through which various stakeholders and other participants can contribute to development. In this regard, landscape-based regional design

is a transdisciplinary undertaking that sees engineering and ecology specializations merge with spatial design thinking while also involving the ideas and knowledge of local residents. It can therefore be described as an integrative platform that organizes the physical environment, individuals and information, governance and their interaction at distinct scales through space and time (Nijhuis, 2019).

At the heart of landscape-based regional design is a strong interaction between research and design. This implies that the analytical capacity of research is closely connected to the explorative power of design. Next to typical forms of research that serve as input for design, the design process itself is employed as a vehicle not just to frame spatial problems visually but also to explore multiple possibilities and generate various solutions. Therefore, research through design can be regarded as a powerful research strategy in which complex spatial problems are approached in a creative and integrated manner. The targeted explorative process plays a central role in which thinking and producing go hand in hand. Research through design implements mechanisms of research and design that are combined with imagination, creativity, and innovation. It also reveals areas in which action, observation and searching can be applied to achieve new insights.Therefore, mapping and drawing are important tools for visual thinking and communication (Nijhuis, 2013).

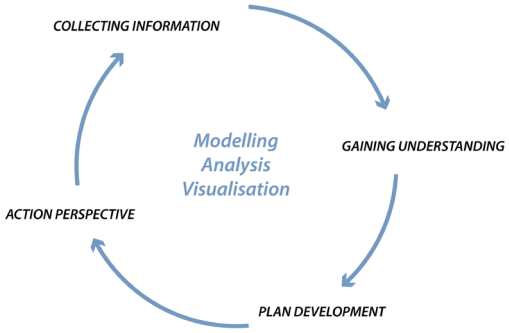

Figure 3. Four important phases in landscape-based regional design (source: Nijhuis, 2015).

4. Key phases in the regional design process

Landscape-based regional design consists of at least four iterative phases: collecting information, gaining understanding, plan development and action perspective (Figure 3).

4.1 Collecting information and gaining understanding

Before launching the design process, the objectives of the regional strategy must first be identified, based on a proper understanding of the site, particularly its challenges and potentials. For this it is necessary to collect and create data/information as well as analyzing and evaluating the region at multiple scales, including the identification and support of all relevant stakeholders. A number of important questions should be considered at the beginning of this process, such as:

-How does an area operate at local scale and in the larger regional context?
-What are the spatio-visual, historical, social and ecological structures or processes that determine the region at different scales?
-What is the current functioning of the urban and natural systems?

In order to answer these questions, it is necessary to describe, select and evaluate various spatial elements while also considering aspects of import in comprehensive urban landscape planning and design. During this process of interpreting, synthesizing and applying data, the individual acquires knowledge. The process is about exploring, analyzing and synthesizing data and information in order to increase the level of understanding on (aspects of) the region in terms of spatial relations, structures and patterns. Understanding (or 'insight') is the application of knowledge to increase effectiveness and to exercise judgement in order to add value (Rowley & Hartley, 2006). In this process, it is crucial to secure the participation of experts and stakeholders such as governmental officials, land owners and community representatives to develop a robust and inclusive understanding of the region. These different perspectives will bring fresh and complementary insights, creating a more complete picture. The various perspectives can be shared and synthesized, primarily via interactive participatory workshops; at the same time, interviews, observations and questionnaires can provide important additional clues. This co-creation of knowledge leads to a shared understanding of the characteristics of the territory as well as helping to identify the main challenges and opportunities for spatial development. Outcomes are agreed collectively and supported by pointers and specified values to ensure inclusive plan development and action perspectives.

4.2 Plan development and action perspective

Once the analysis and evaluation phase is finalized and the main challenges and opportunities have been determined in a participatory and inclusive way, the next step is to explore and develop various integral and multiscale design strategies and principles, especially regarding their potential. Typical questions here are:

-What can be done to address the challenges of the area?
-How can the potential of the region be exploited by means of multiscale projects?
-What are the key spatial structures and processes that need to be addressed and coordinated at regional scale?
-What are the strategic locations?
-Which favourable conditions that can be fostered at regional scale?
-What are the implications for on-going projects in the region?
-Which important stakeholders should be involved to ensure social-economic and ecological embedment?
-Are there any instructive (international) precedents?
-In which ways do long-term strategies and short-term design interventions interrelate, and how can they reinforce one another?

Previous studies as well as scenario building and research through design can all be exploited to answer these questions. Design thinking is also a useful way of exploring the spatial possibilities of various design strategies and principles. The keywords in this part of the process are innovation, creativity and imagination. Design strategies and principles are also explored visually while their feasibility is evaluated by designers, specialists and stakeholders. This process can also include computer models, field experiments and modelling to aid visualization and testing as well as to generate ideas. Questions that need to be addressed in this phase include:

-Which spatial-planning design strategies and principles are most promising?
-How can they be applied at multiple scales in the region, and what are the probable outcomes?
-What is the optimal solution from a spatial, social and ecological point of view?
-Is it possible to introduce historical aspects to the design?
-How can the plan be adapted to and strengthen the regional identity?
-Does the design allow for change and flexibility over time?
-How can the composition of land use-patterns, vegetation, water, urban typologies and other elements facilitate ecosystem services as well as cultural expression?

Regional design is not just a platform to prioritize, integrate and organize physical structures through the application of planning and design skills; it also requires responsible authorities to align their spatial policies towards a long-term strategy. However, new governance arrangements often need to be developed to create the right conditions for important design elements such as the realization of local projects. To this end, it is vital to involve relevant policymakers, governmental authorities as well as other stakeholders, who must all be engaged from the early stages of the planning process.

5. Understanding the PRD as a complex system

The PRD's urban landscape can be viewed as a complex system consisting of subsystems, each within its own dynamics and velocity of change (Meyer & Nijhuis, 2013). Understood as a system, the urban landscape is a material space structured as a constellation of networks and places with various organizational levels that address distinct spatial and temporal dimensions (Doxiadis, 1968; Otto, 2011; Batty, 2013). Here, the concept of *longue durée* is essential, emphasizing the long-term and persistent structures of an urban landscape under constant change. According to French historian Fernand Braudel (1966), the first level of dynamics, which is rooted in the natural environment, is characterized by a slow process of almost imperceptible transformation, repetition and natural succession; the second level is linked to long-term social, economic and cultural history; the third dynamical level is that of short-term human and political occurrences. In short, the urban landscape is continually developing through the action or interaction of natural and human structures, patterns and processes that depend on ecological, socio-cultural, economic and political factors.

5.1 Mapping landscape systems

The spatial relationships between environmental circumstances and human actions or interventions can be studied by means of cartographic explorations (i.e. mapping) to identify important conditions, critical driving forces and the effects of distinct dynamics. The mapping of landscape systems is different from the suitability maps as proposed by McHarg (1969). In the former, maps are created to understand spatial relationships and the dynamic of change rather than indicating areas where urban developments (for example) can take place. Maps of landscape systems reveal the spatial conditions that inform adaptive planning strategies and design principles. Decomposing the urban landscape into layers according to the dynamic of change is a proven method to help understand the urban landscape system (Nijhuis & Pouderoijen, 2014). Layers with a low dynamic of change are the substratum (e.g. topography, hydrology, soil) and climate (e.g. precipitation patterns, temperature, wind). These environmental factors, regarded as

the most influential conditions for land use, are known as *first tier conditions*. Infrastructural networks for transportation, water management and energy supply are grouped in another layer, termed *second tier conditions*. Displaying quicker growth and change than the first-tier environmental conditions, these are also significant conditional variables for land use. Together, these first and second tier conditions together pave the way for the development of agricultural land use and urban settlements, resulting in the layer with the highest change and transformation dynamics (Nijhuis & Pouderoijen, 2014) (Figure 4).

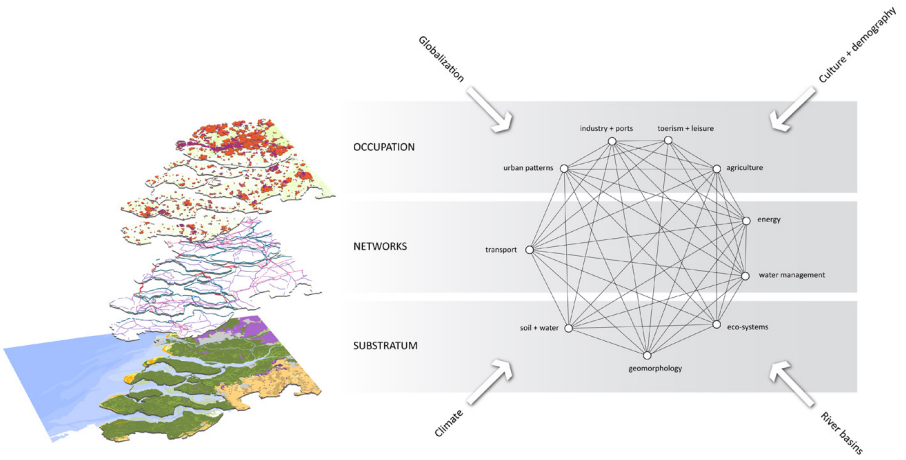

Figure 4. Understanding the urban landscape as a layered and complex system (image: Steffen Nijhuis).

6. Mapping the PRD's natural and urban system

In order to understand the natural and urban system of the PRD, three maps were constructed based on available knowledge and input from experts and stakeholders. Drawn up in a participatory process, these maps show the core physical structures and characteristic patterns of the PRD to illustrate the dynamic of the territory, the natural and urban system and their interactions. Specifically, they show the eco-agricultural system, the urban system, the infrastructure networks and urban tissue, and their relationships.

The basic components of the natural system are the climate, landforms, water and rock type. These drive the formation of soils, determine hydrology as well as the distribution of ecosystems, agricultural land-use and historical settlements or cities. The PRD can be divided into two geomorphological types. The western part of the delta is a river-dominated plain formed over the course of the past millennia by natural processes such as siltation and deposition (Figure 5).

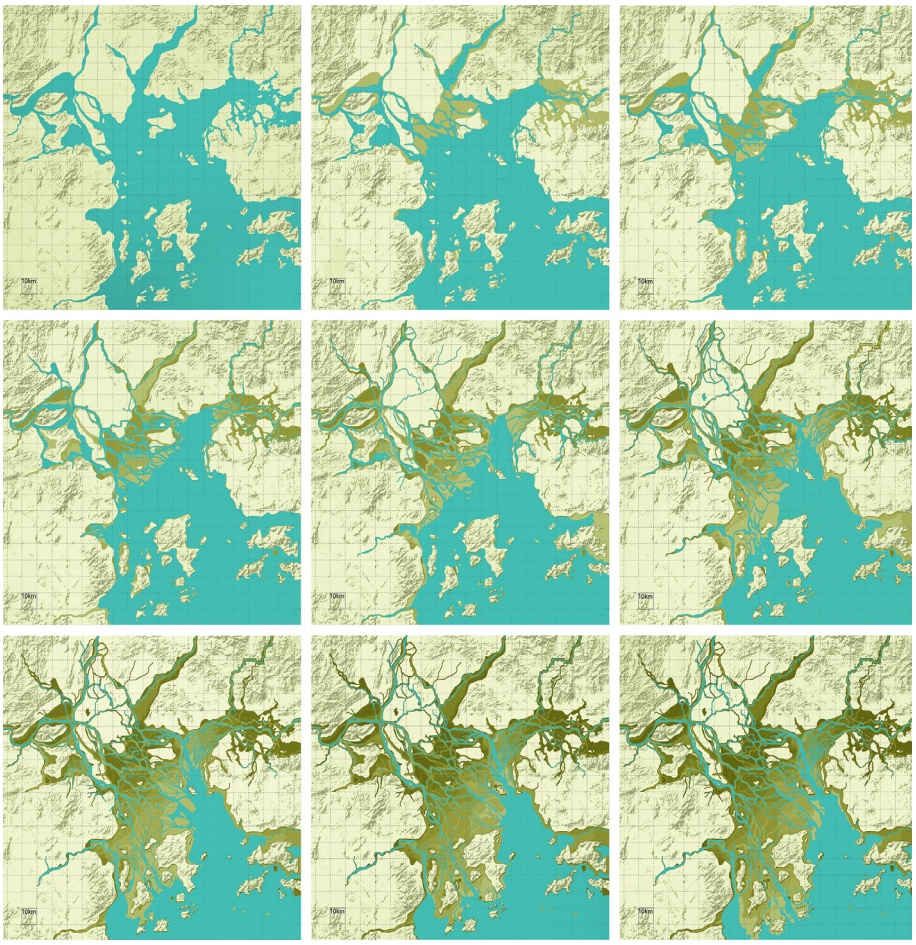

Figure 5. Landscape formation of the PRD from 4000 BC to 2015 AD (source: Xiong & Nijhuis, 2018).

The estuary to the east is tide-dominated (Xiong & Nijhuis, 2018). Almost 90% of the land in the PRD is flat terrain, with the remaining 10% made up of 160 hills and 187 islands spread around the coast (Huang & Zhang, 2004). The deltaic lowland is characterized by two sub-deltas and a tidal estuary. The rivers that dominate the PRD are the West River, the North River and the East River. Together they form a drainage basin of 453,690 km2 and have a total length of 2,200 km (Zhang et al. 2008). The most important river in terms of discharge and sediment load is the West River (80% of total water discharge, 90% of total sediment load). Seasonal flooding is a common characteristic in the West and North River sub-deltas, primarily in the period from April to September. The estuary also suffers from extreme tides induced by typhoons or storm surges, mainly occurring in the typhoon season from July to September.

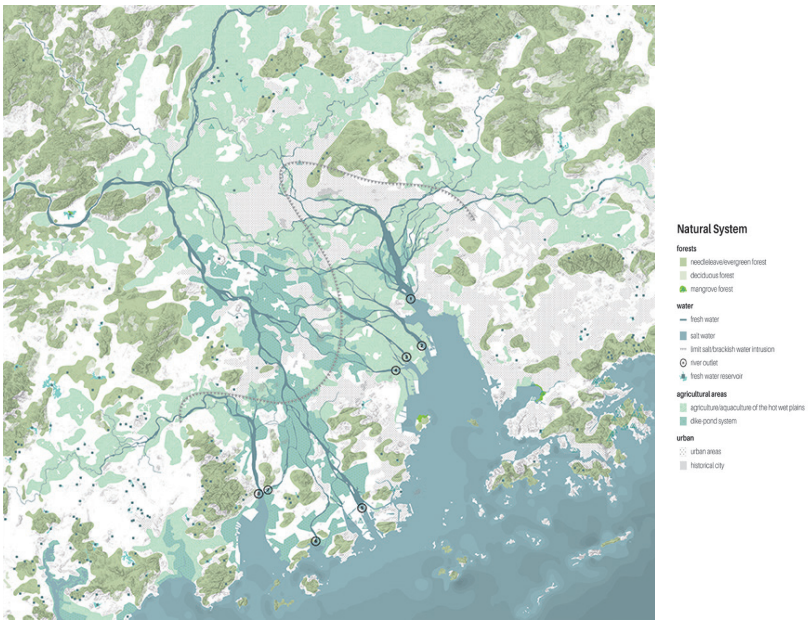

Figure 6. A map showing the eco-agricultural system of the PRD (Map: Steffen Nijhuis, Daniele Cannatella & Liang Xiong, 2019)

The wet and flat topographical features of the PRD provide favourable conditions for wetland ecology as well as urban development and agriculture, confirmed by the long history of extensive agricultural activities stretching back more than 4000 years. This has proven to be a sustainable human-environment relationship in the ever-changing wetland environment that has arisen through frequent flooding and the continual seaward expansion of the land (Weng, 2000; Zhao & Yang, 2011). Due to the wet and flat conditions of the terrain, the local population developed over many years sophisticated multiscale, water-sensitive farming methods in the warm hot plains known as agri-aquaculture. For centuries this formed the basis of the local economy. One of the most notable of these methods, developed from the 14th century onwards in the sub-deltas, is the dike-pond system in which fish ponds are constructed between dykes bearing fruit trees (Ruddle & Zhong, 1988). By the early 17th century, the fruit trees were replaced by mulberry trees to facilitate silk production while four species of fish were farmed in the ponds. Subsequently, this type of agri-aquaculture pattern continued to grow and prosper until it hit a peak around the 1920s (Ruddle & Zhong, 1988). Today, most of these areas still feature fish ponds alongside industrial plots and urban settlements, but almost without silk production.

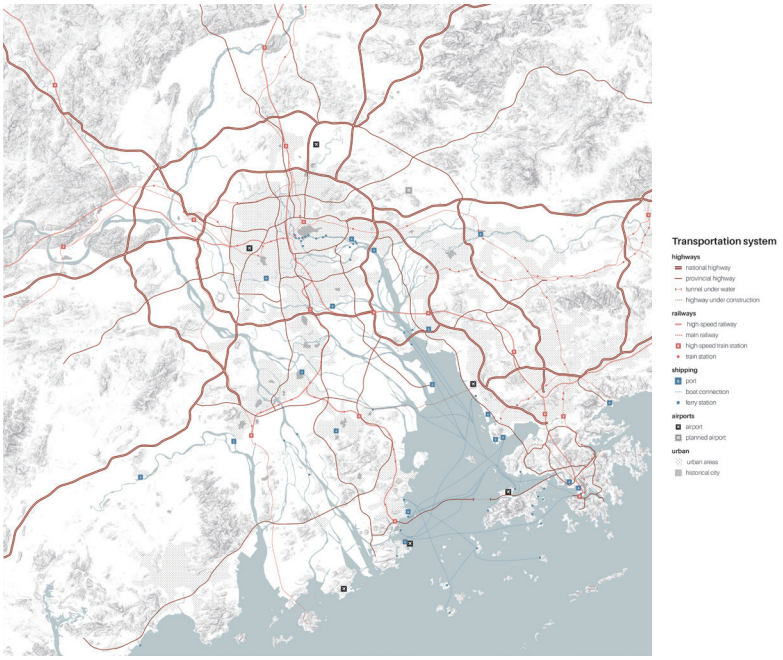

Figure 7. A map of the PRD's infrastructural system
(Map: Steffen Nijhuis, Daniele Cannatella & Liang Xiong, 2019)

Reflecting the area's large bays and riparian zones, the natural vegetation in the PRD is largely mangrove forest, wetland and wet forest. While individual mountains and ridges have traditionally hosted dry forests, large swathes of woodland were cut down in previous decades; today the process of replanting the trees has started . At the foot of the slopes, basins have been established for the supply of fresh water as well as for irrigation (Figure 6).

In the pre-industrial period, the region relied heavily on water-borne transportation. From the 1950s, however, the shift from private to public ownership of land enabled major infrastructural developments in the PRD. Large-scale dike reconstructions (Xiong & Nijhuis, 2018), the development of a vast network of (high-speed) train connections and an expansion in road infrastructure all helped to foster the region's rapid urban expansion. Well-developed road and train infrastructure can be found in the corridors from Guangzhou-Shenzhen/Hong-Kong and Guangzhou-Zhuhai/Macau. The ports of Hong Kong and Nansha are important transportation hubs, as are the international airports of Hong Kong and Guangzhou (Figure 7).

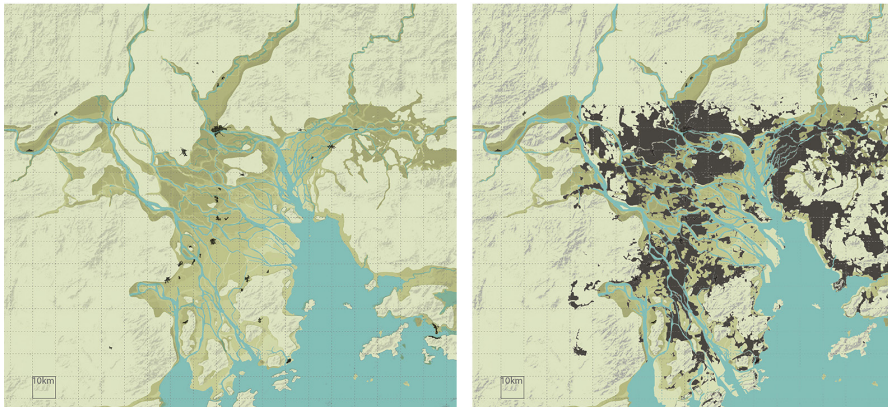

Figure 8. Urban development from 1950-2015 (source: Xiong & Nijhuis, 2018).

The histories of ancient cities such as Guangzhou, Foshan and Macau can be traced back more than 2000 years. In Guangzhou, for instance, archaeologists discovered the remains of a large royal garden and palace from around 203 BC, showcasing the rich culture of the Nanyue kingdom (Wu & Chen, 2010). It is interesting to note that the historic Lingnan gardens in the Guangdong province, with their traditional architecture, were clearly adapted to the specific climatic conditions regarding site selection, orientation, layout and construction materials, all of which had a positive impact on the micro-climate. In general, the cores of these historical cities are all oriented towards rivers and the coast for strategic reasons as well as to facilitate transportation.

From the 1950s onwards, the historical cities have benefited from infrastructural investment. In the 1980s, China created the PRD Special Economic Zone to attract foreign investment, turning the area into the world's fastest urbanizing delta (Figure 8). This gave the Pearl River Delta a certain degree of autonomy in terms of customs, finance and taxes. Manufacturing companies opened numerous factories, creating a thriving economy. During the process of urbanization, large areas inside the polders were transformed from farmland into urban settlement. According to the Guangdong Statistical Yearbook of 2016, there are now 60 million inhabitants in the PRD, a figure expected to rise to 80 million by 2030.

Within this wide-ranging urban development, different spatial patterns can be discerned: in the north, fairly concentric patterns of development are found around the historical town cores; in the east, urbanization has followed a more linear pattern along the coastline, where new settlement areas are hemmed in by mountain ridges; finally, in the west, we can observe more dispersed patterns, reflecting the traditional polder fields of this area. Today the epicentre of urbanization is the urban corridor Guangzhou-Shenzhen, with an important role for Nansha as a connection hub (Figure 9).

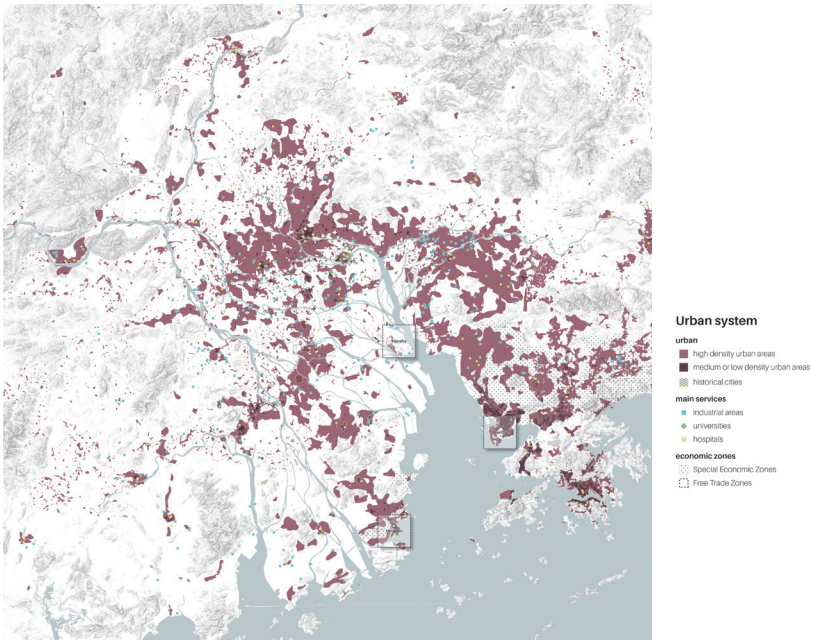

Figure 9. A map of the structure of the PRD's urban tissue (Steffen Nijhuis, Daniele Cannatella & Liang Xiong, 2019).

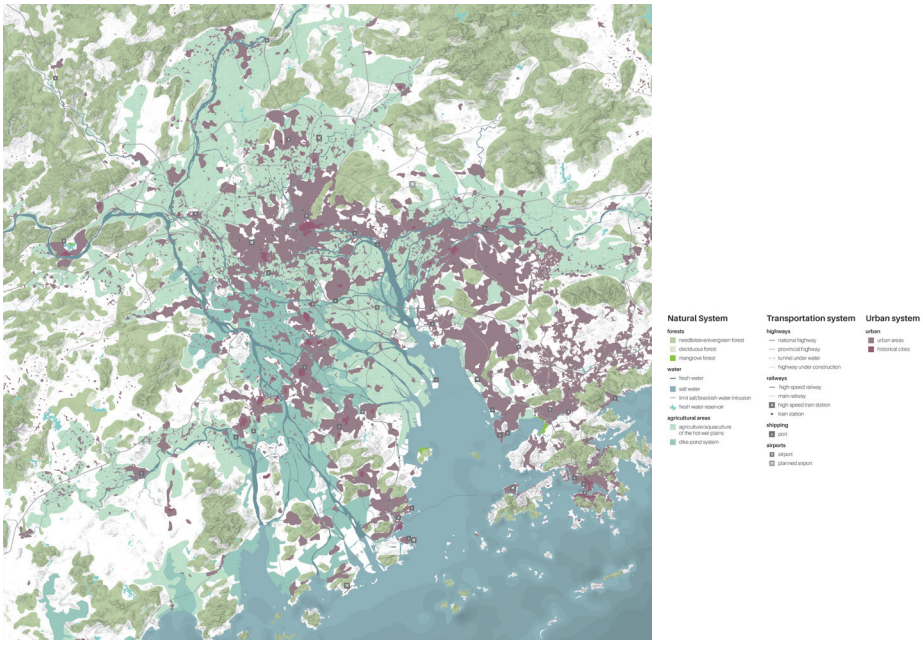

Figure 10. The urban landscape of the PRD (Steffen Nijhuis, Daniele Cannatella & Liang Xiong, 2019).

The synthesis map (Figure 10) shows the urban landscape resulting from the interaction between environmental conditions (e.g. substratum and climate) and the infrastructural networks for transportation, water management and energy. These conditions have paved the way for the development of agricultural land uses and urban settlements, leading to the layer with the highest dynamics of change and transformation. However, the fast pace of urbanization and climate change have led to some severe problems. Alongside rising sea levels, unpreceded storm surges from typhoons and increased river discharge have resulted in the frequent flooding of urban areas. The risk of flooding has been increased by the canalization of rivers with insufficient capacity to cope with additional discharge. Large farming areas have been transformed into industrial sites and urban areas, thereby greatly reducing their rainwater absorption/storage capacity and thus the ability to mitigate not only the risk of flooding but also water shortages. Natural mangrove forests have been cut down, making coastal areas more vulnerable to flooding. In addition to flooding, the PRD is also suffering from subsidence, saltwater intrusion, smaller areas of farmland (and thus lower food production), socio-economic problems as well as the loss of important ecological and cultural-historical sites. The collective recognition of these challenges and opportunities underlies efforts to realize a more sustainable and inclusive strategy for planning and design in the PRD.

7. Towards a sustainable future for the PRD

Adaptive urban transformations form the basis for a landscape-based regional strategy to address the main challenges and potentials of the PRD. In this strategy, natural and urban dynamics as derived from systems analysis must set the pace and nature of adaptation. The plan development and subsequent implementation will focus on the potential of interlinked economic and ecological development at multiple scales. The goal is to facilitate sustainable transformations of old industrial/housing areas as well as the region's agricultural landscape, thereby removing constraints on the expansion of built-up areas and thus accommodating continued economic and population growth. These areas, which possesses good spatial conditions for long term economic development, are generally located on newly reclaimed land within the delta's estuaries, featuring a dense network of waterways, vast areas of fishing ponds as well as wetlands and agricultural land; they contain highly sensitive ecosystems and are vulnerable to flooding. In this phase, the possibilities for the development of regional green-blue infrastructure and city-level water networks are identified with the aim of increasing adaptive capacities, ecosystem services as well as water safety.

Figure 11. Exploring future scenarios for the spatial development of the PRD (photo: Steffen Nijhuis, 2018).

7.1 Scenario studies

Scenario studies have been employed to investigate the PRD's likely future development. Through a combination of empirical data, forecasting and imagination, it is possible to identify critical key locations, driving forces and likely impacts of future events, whether opportunities or threats (Meyer & Nijhuis, 2016) (Figure 11). Scenario building constitutes an useful instrument to address uncertainty and to generate understanding about trends and their relationships as well as new challenges or policies and their effects. It also structures strategic discussions and facilitates the involvement of diverse stakeholders (Dammers et al. 2013, Veeneklaas & Van den Berg, 1995). In the current case, the scenarios are conducted in an academic setting with the involvement of governmental authorities and water boards. In order to build a scenario, it is necessary to formulate an internally consistent and coherent set of hypotheses on the primary relationships to be explored. On the basis of these assumptions, a systematic yet selective description of the current scenario can be made, identifying the most significant external variables that determine the course of spatial development (Veeneklaas & Van den Berg, 1995).

7.2 Developing a regional strategic vision

Together with the assessment of urban landscape growth over time and the evaluation of present spatial development projects in the region, several

significant factors of future development have been identified, leading to an initial strategic vision for the PRD. This vision needs further elaboration, based around the idea that the PRD will develop into China's Silicon Valley, with strongly developed and well-connected urban qualities, robust green-blue frameworks, cultural-historical assets connected to the region and water sensitive socio-ecological inclusive urbanism. According to the initial idea, the East wing (Guangzhou-Hong Kong corridor) of the PRD will further develop into a well-connected red-green necklace, where strong urban hubs and marinas alternate with robust green corridors connecting the mountains to the sea. With the development of wet plains, the West wing will be transformed into a blue axis featuring water sensitive ecological agri-aquaculture and considerable flood retention capacity, complemented by strong urban hubs that benefit from transit-oriented development (TOD).

7.3 Transformation perspectives

The primary use of the regional strategic vision is to determine priorities in spatial planning and design. Backcasting is used to identify spatial transformation perspectives that help accomplish the objectives set by the strategic plan, and guide actions accordingly. The spatial transformation perspectives provide a set of adaptive design strategies that are specific to the challenges and potentials of the territories in the sub-deltas and the PRD estuary. The perspective of each transformation has spatial dimensions, namely: water sensitive and socio-ecologically inclusive, flexible and multifunctional, addressing multiple temporal and spatial scales. In the sub-deltas, the transformation perspectives are connected to river and rainwater adaptive approaches, encompassing design principles for resilient riverways, integrated agri-aquaculture, sustainable urban transformations, new urban districts, the integration of (historical) villages, industrial transformation and eco-tourism. In the estuary, the transformation perspectives are mainly connected to seawater adaptive approaches, encompassing design principles for multifunctional flood protection, harbour and marina development, land reclamation (sedimentation, erosion), the development and transformation of waterfronts as well as the protection and development of mangroves and other coastal ecosystems.

Each of these transformation perspectives must be elaborated into more detail. Design principles can be identified by studying relevant and successful (international) cases. In addition, their potential should be explored by means of a process of research through design. Strategic areas can serve as experimental sites to test the possibilities of application in a spatial and visual way. Sun, Nijhuis & Bracken (2019) provides details of a multiscale water-sensitive design of agri-aquaculture in the PRD.

Figure 12. Thinking together about the future of the PRD using a digital map table (photo: Steffen Nijhuis, 2018).

7.4 Action outlook

In order to put the gained knowledge and ideas into action, it is important to address the question of whether the right conditions for new governance arrangements can be created. Therefore, the regional design demands investigation of ways in which different stakeholders could collaborate on, agree to and fine-tune a design. As discussed, the regional design process must facilitate an understanding of urban landscape dynamics and transformations through an *ex post* evaluation of existing urban planning strategies and projects as well as an *ex ante* evaluation of scenarios of potential adaptation strategies (Nijhuis, Sun & Lange, 2017). Here communication is a central issue. In particular, it is vital to develop and utilize innovative visualization methods and tools that aid the involvement of local stakeholders and decision-makers. Throughout the process, interviews and workshops with stakeholders are organized to explore potential areas of agreement. During the workshops, stakeholders are brought together around digital map-tables (Figure 12) that illustrate the relationships between different systems. Augmented and virtual reality tools can also be employed (see e.g. Tomkins & Lange, 2019), enabling participants to see the potential repercussions of their initiatives on other systems. These innovative visualization methods serve to speed up discussions of different proposals with all stakeholders and form the basis for the further development of the regional vision and related strategy. These transformation perspectives will guide the development of the delta towards a more sustainable future.

8. Conclusion

As discussed, the PRD's urban landscape is the result of various processes and systems that display different dynamics of change and which impact on each other. The ability to interrelate systems through spatial design has become increasingly important, as the interconnection of different systems and their formal expression is a fundamental aspect of contemporary regional development.

Here we advance landscape-based regional design as an inclusive planning and design approach for the adaptive transformation of the PRD. In the above, an approach to this form of design has been outlined rather than any specific outcome. At a time of complex challenges, the development of alternative approaches such as this offers a pathway to realizing socio-ecological inclusive design processes as well as modes for collaboration amongst disciplines and stakeholders. Landscape-based regional design stimulates cooperation between disciplines such as architecture, urban planning and landscape architecture. It also reviews the agency of spatial design in giving shape to the built environment. Furthermore, as an inclusive design approach, it establishes relationships between ecological and cultural factors, between process and form, between long-term and short-term developments as well as between regional strategies and local interventions. As such, landscape-based regional design is a powerful vehicle for guiding territorial transformations in a process of creating local identity and safeguarding regional relationships, while simultaneously linking ecological and social processes to urban forms.

In sum, landscape-based regional design brings new operational power to spatial design – as an integrative, creative activity – and recognizes the regional urban landscape as a significant field of inquiry, one that is context-driven, solution-focused and transdisciplinary.

ACKNOWLEDGEMENTS

This research has been supported by the NSFC, NWO and the EPSRC Joint Research Project: 'Adaptive Urban Transformation (AUT) – Territorial governance, spatial strategy and urban landscape dynamics in the Pearl River Delta' (grant no. ALWSD 2016.013 sustainable delta programme).

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