IDENTIFYING SYNERGIES AND CONFLICTS BETWEEN MITIGATION AND ADAPTATION MEASURES AT THE CITY LEVEL

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March, 2011

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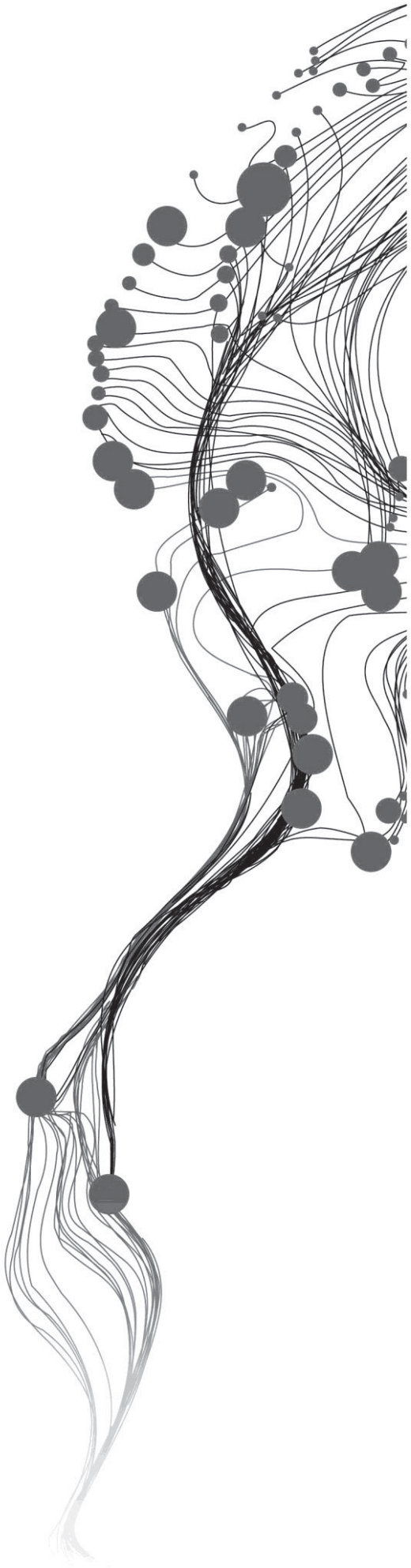

IDENTIFYING SYNERGIES AND CONFLICTS BETWEEN MITIGATION AND ADAPTATION MEASURES AT THE CITY LEVEL

HSIEH, WEI-CHAN
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Thesis submitted to the Faculty of Geo-Information Science and Earth Observation of the University of Twente in partial fulfilment of the requirements for the degree of Master of Science in Geo-information Science and Earth Observation.
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ABSTRACT

Mitigation and adaptation are two major strategies among human society to reduce the risk of climate change. Recently there is a tendency to integrate mitigation and adaptation into one coherent approach. This research aims at identifying synergies and conflicts between mitigation and adaptation measure, which is suggested by previous studies to develop linked mitigation-adaptation strategy. A multi-method approach was applied in this research. Written explicit knowledge, practical experience and tacit knowledge of citizens were extracted to identify the synergies and conflicts. Four situations were identified in which the mitigation or adaptation measures will potentially create synergies; and two situations were identified in which conflicts might happen. In the end, this research recommended that rather than identifying synergies and conflicts, the more feasible option to develop linked mitigation and adaptation strategy is to mainstreaming the idea of mitigation and adaptation into general development policies.

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1. INTRODUCTION

1.1. Research Background

"Mitigation" and "adaptation" means two different major strategies of how people tackle the issue of global climate change. Literally, they can be interpret as "mitigate the driving factors of climate change", and "adapt to the consequences of climate change". A schematic framework is adopted in here to illustrate the whole picture and the relationships between climate change, human society, mitigation and adaptation. Figure 1.1 shows that climate change is driven by the emission and concentration of greenhouse gases due to humans' activities; and at the same time it causes the impacts and vulnerability to the socio-economic development of human society. From the socio-economic development, mitigation strategies are developed to reduce anthropogenic climate change driving factors; and adaptation strategies are applied to adjust the society to adapt to incoming impacts due to climate change. This research is built under this context. It is especially interest in the relationship between mitigation and adaptation. The rest parts of this section will further provide the readers an introduction on the issue of climate change, the roles of mitigation and adaptation, and the emergence of the tendency to integrate mitigation and adaptation.

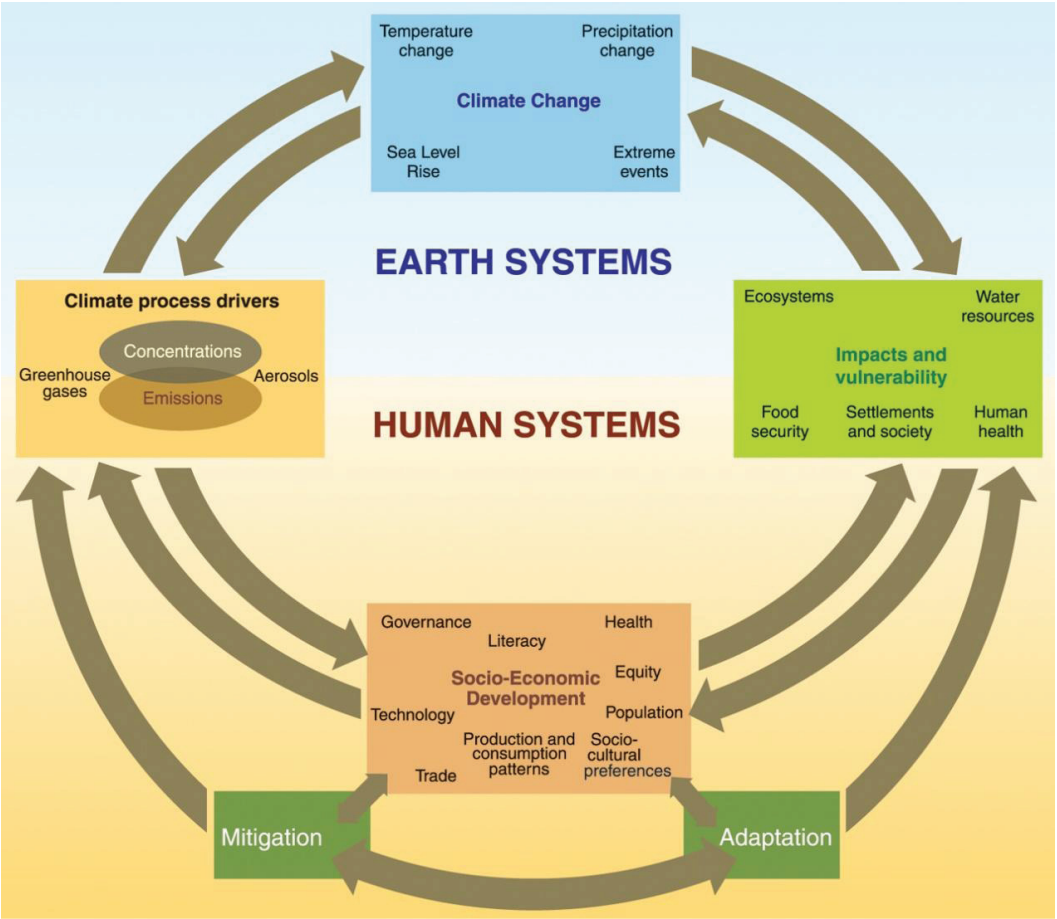

Figure 1.1 Schematic framework representing anthropogenic drivers, impacts of and responses to climate changes, and their linkages. Adopted from IPCC (2007c)

A serious change in the Earth's climate system over last decades has been observed. It has been realised that this intensive climate change is human-induced; and the main source of this change is the greenhouse gases emissions from human activities (Karl & Trenberth, 2003). The anthropogenic greenhouse gases emission changes the composition of the atmosphere. Any change in the atmosphere system requires a new equilibrium to be maintained, eventually it drives the climate change global wide (Chapman, 2007). The primary consequence of increased greenhouse gases concentration in the atmosphere is that the greenhouse effect is enhanced. Whilst there is more outgoing solar radiation from the Earth to space trapped by the greenhouse gases, the Earth's surface temperature starts to rise. This fact is normally known as "global warming" (Karl & Trenberth, 2003).

However, the increased temperature also leads to other effects and changes in the climate system. Higher temperature not only changes the form of precipitation – which is more likely to fall as raining rather than snowing, but also strengthens the water-holding capacity of the atmosphere, which ultimately changes the pattern of precipitation. Whilst the frequency and duration of precipitation are reduced, the intensity is augmented. Furthermore, the strengthened water-holding capacity of the atmosphere also results in more evaporation from the lands, which eventually increases the likelihood of drought in the dry regions or dry seasons. Another major effect of the climate change is that the average global sea level is now gradually rising. It is because of the melting of land-based ice and the thermal expansion of water body – both of them are the consequences of increased Earth's surface temperature. (IPCC, 2007d; Karl & Trenberth, 2003)

Although some of aforementioned effects would be beneficial to the society, for instance, decreased number of cold days due to increased average temperature leads to the reduction of winter maintenance cost in transport infrastructure, and new sea passages in polar regions (Jaroszweski, Chapman, & Petts, 2010); most of climate-associated phenomena are threatening the human society, for instance, food shortage in drought areas, heat stress in built environment, raised incidence of flooding in the low lying areas, and storm threats and sea level rise in coastal regions (IPCC, 2007a). There are mainly two strategies among human society to deal with the issue of climate change, namely mitigation and adaptation. In simple words, mitigation means the actions to reduce anthropogenic greenhouse gases emissions (the driving factor of climate change); adaptation means the actions which aim to cope with current and expected climatic impacts (the consequences of climate change) (Swart & Raes, 2007). Numerous of mitigation and adaptation measures have been implemented in different levels; for instance, mitigation policies which are promoting public transport and zero-carbon modes (Chapman, 2007), and adaptation programmes such as dike construction and underground water storages (de Bruin et al., 2009).

In spite of that both mitigation and adaptation are aiming to reduce the risk of climate change, they were traditionally perceived as two separate strategies by either academics and policy makers (Swart & Raes, 2007). However, there is a tendency emerged recently among scientific group to explore the possibility to integrate mitigation and adaptation into one coherent framework (Ayers & Huq, 2009; Dang, Michaelowa, & Tuan, 2003; Klein, Schipper, & Dessai, 2005; Laukkonen et al., 2009; McEvoy, Lindley, & Handley, 2006; Swart & Raes, 2007; Wilbanks, Leiby, Perlack, Ensminger, & Wright, 2007; Yohe & Strzepek, 2007). The main reason to develop an integrated mitigation-adaptation approach is the realisation that both mitigation and adaptation are necessary and needed to be implemented at the same time. Singly rely on the mitigation will not able to cope with the climate change in the next few decades because of the lag time of the climate system. Moreover, the impacts of climate change are already being observed, adaptation is therefore necessary (Klein, et al., 2005). "There is high confidence that neither adaptation nor mitigation alone can avoid all climate change impacts. Adaptation is necessary both in the short term and longer term to address impacts resulting from the warming…Adaptation and mitigation can complement each other and together can significantly reduce the risks of climate change." (IPCC, 2007c) Furthermore, it is

possible that an integrated approach can offer benefits over two independent strategies by creating synergies between mitigation and adaptation and avoid trade-offs (Swart & Raes, 2007).

1.2. Research Justification

This research is therefore placed in this context. It serves to support the development of integrated mitigation-adaptation approach to tackle the issue of climate change. Swart and Raes (2007) purposed that identify synergies and avoid trade-offs are two of many ways to develop the linked mitigation and adaptation strategies, notably in land use and urban planning sector which plays an major role in both mitigation and adaptation. It is a challenge for decision makers to understanding the linkages, synergies and conflicts between mitigation and adaptation measures, especially in the urban area – "where most of the population is concentrated and where its impact is likely to be most keenly felt." (McEvoy, et al., 2006)

Some of previous studies have identified few examples of synergies which achieve the objectives of mitigation and adaptation at the same time, for instance, increase energy efficiency and reduce energy dependency (Swart & Raes, 2007), and few examples of conflicts, for instance, urban densification which helps in reducing greenhouse gases and energy uses but have negative implications for adaptation (Hamin & Gurran, 2009; McEvoy, et al., 2006). However, they recommended further researches to broaden the menu of mitigation and adaptation options and the analysis of their linkages (Swart & Raes, 2007), and especially for the cases of potential conflicts (Hamin & Gurran, 2009).

1.3. Research Problem

The climate change which is driven by anthropogenic greenhouse gases emission is now threatening the human society. The impacts occur in many forms: increased average temperature, intense rainfalls, flooding, drought as well as sea level rise (IPCC, 2007d). Two major strategies – mitigation and adaptation – have been implemented to deal with the issues. Whilst mitigation aims at reducing the driving factors of climate, adaptation aims at adjusting the society to the consequences of climate change(Swart & Raes, 2007). Because of the necessity of both mitigation and adaptation (IPCC, 2007c; Klein, et al., 2005), there is a tendency emerged trying to develop an integrate mitigation-adaptation approach instead of treating them separately – the way they used to be treated (Swart & Raes, 2007).

Swart and Raes (2007) suggest many ways to develop linked mitigation and adaptation strategies, including identify synergies and avoid trade-off. Yet, in terms of finding out the contradictions between mitigation and adaptation measures, it is surprised that "…little research exists on the types of conflicts that might arise in practice" (Hamin & Gurran, 2009). Whilst few examples of synergies and conflicts have been identified (Hamin & Gurran, 2009; McEvoy, et al., 2006; Swart & Raes, 2007), previous studies called for further studies to broaden the analysis to identify the linkages (Swart & Raes, 2007), especially at the city level – where the many mitigation and adaptation actions are implemented (Swart & Raes, 2007) and where the population is concentrate in (McEvoy, et al., 2006).

1.4. Research Aim, Objectives and Questions

1.4.1. Research Aim

This research aims to conduct investigations to study the synergies and conflicts between climate change mitigation and adaptation measures at the city level.

1.4.2. Research Objectives and Questions

The research questions are listed below the research objective which they relate to:

Objective 1. To analysis current mitigation and adaptation measures.

Q 1.1. What are common mitigation and adaptation measures?
Q 1.2. What are the objectives of these mitigation and adaptation measures?

Objective 2. To identify the synergies and conflicts between mitigation and adaptation measures.

Q 2.1. What measures potentially create synergies?
Q 2.2. What measures potentially cause conflicts?
Q 2.3. In what conditions synergies and conflicts may happen?

Objective 3. To study the synergies and conflicts from different perspectives.

Q 3.1. What synergies and conflicts can be found from existing literatures?
Q 3.2. What synergies and conflicts can be found from practical experience?
Q 3.3. What synergies and conflicts can be found from citizens' perception?

1.5. Conceptual Framework

The conceptual framework is illustrated in Figure 1.1. This research intends to study the synergies and conflicts between mitigation and adaptation measures at city level from three perspectives: an academic perspective studying explicit knowledge in form of textbook, scientific reports and journal papers, a practical perspective looking at a case study and studying knowledge gained whilst developing and implementing mitigation and adaptation plans, and finally the perspectives of the perception of citizens trying to capture implicit, tacit knowledge about synergies and conflicts between mitigation and adaptation. Three different investigations with different methods are then designed to extract the information from these three perspectives (knowledge sources). The benefit of gaining information from more than one source on the same topic is that a more comprehensive view can be obtained, furthermore, a multi-method set-up has "…the potential of exposing unique differences or meaningful information that may have remained undiscovered with the use of only one approach or data collection technique in the study." (Thurmond, 2001)

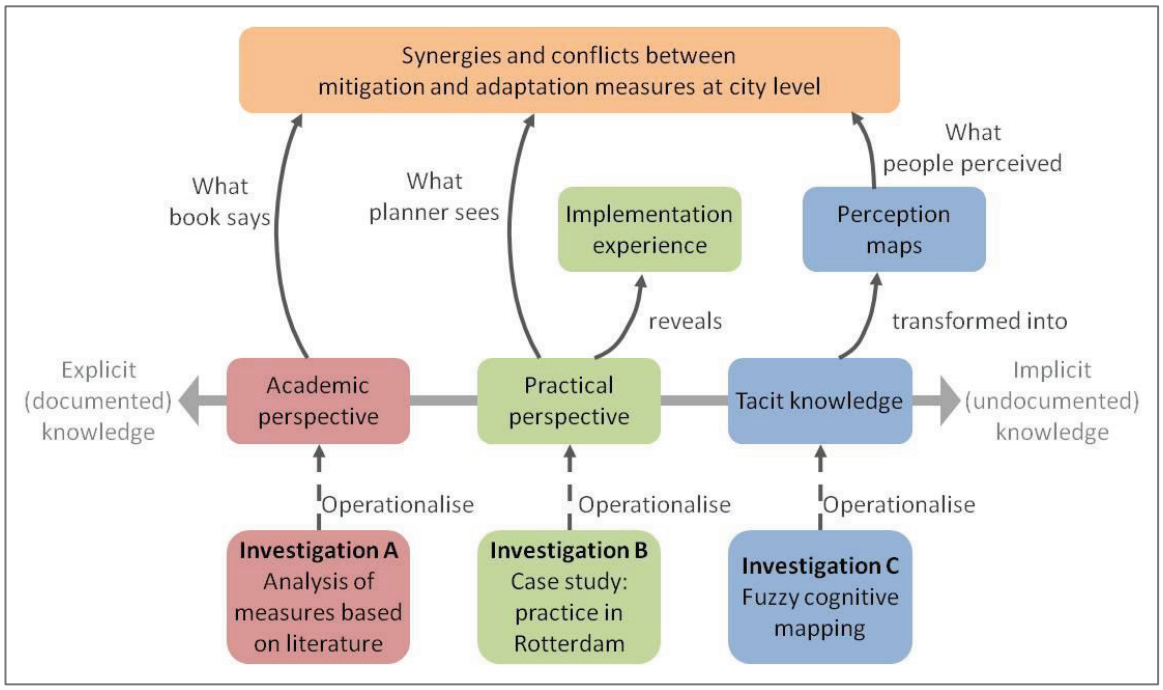

Figure 1.2 Conceptual framework

From the academic perspective, information from the explicit knowledge is expected to be extracted. Explicit knowledge is the knowledge has been codified and documented (Anand, Ward, & Tatikonda, 2010). In this case, the existing literatures are the knowledge sources. An analysis is designed to identify common mitigation and adaptation measures from the literatures and further to find out the synergies and conflicts. In other words, this part of the research is built on "what the book says" – the knowledge has been written. Moreover, the finding of this analysis will sustain the research as a theoretical base – which is essential when a multi-method research approach is applied (Thurmond, 2001).

Rotterdam is chose as the case to study the topic from the practical perspective since both mitigation and adaptation measures are currently largely invested in the city. This part of the research extracts information based on the experiences from the planners in Rotterdam – what synergies and conflicts they have seen, and what they have not seen. However, in order to judge whether they have seen or not seen the synergies and conflicts, an analysis on mitigation and adaptation measures – which are identified from documents – are necessary to generate comparable result. In addition, the implementation experiences are planned to be obtained by the case study. The purpose is to understand whether there are any barriers against facilitating the synergies in the practice and not yet been documented by academic community.

Tacit knowledge is generally defined as opposite of explicit. It is rather implicit, difficult to codified and articulated, and has a personal nature (Boiral, 2002). Furthermore, tacit knowledge is subjective and based in individual experience (Anand, et al., 2010). Boiral (2002) has revealed that, in the environment management, tacit knowledge of industrial firms' employees can be useful in identification of pollution sources, management of emergency situations, and development of preventive solutions. It is because of that the firms' employees are close to the pollution sources, and they are relatively more sensitive to the abnormalities according to their working experiences, therefore their tacit knowledge can contribute to the development of solutions. Reflecting to the context of climate change, tacit knowledge of people who can sense the sources of greenhouse gases emissions and the impacts of climate change can be useful to identify the mitigation and adaptation measures. Therefore the third part of the research is designed for applying the method of fuzzy cognitive mapping to capture the tacit knowledge and transform it into directional graphs (perception maps) which are capable to be combined with each other. By combining individual maps, the perception maps of mitigation and adaptation produced; and from these two maps synergies and conflicts can possibly be identified.

1.6. Thesis Structure

The rest chapters of this thesis report are structured as follow:
Chapter 2 presents the literature review on the issue of climate change, the development of mitigation-adaptation integration and the previous studies which tried to study the synergies and conflicts between mitigation and adaptation.
Chapter 3 describes the methodology applied in this research.
Chapter 4, 5 and 6 present the main findings of the three investigations respectively.
Chapter 7 discusses the findings by cross checking the results of each investigation; and the conclusion will be drawn in the end of the chapter.

2. LITERATURE REVIEW

The first part of this chapter presents the present knowledge which forms the background of this research – the issue of climate change, the roles of mitigation and adaptation, and the development of integrated mitigation-adaptation approach. The second part of this chapter presents the review of previous literatures which tried to identify the synergies and conflicts, and their methodology will be discussed. The last part presents an introduction of the method of fuzzy cognitive mapping – which is purposed to be applied in this research.

2.1. Climate Change and the Effects

2.1.1. Cause of Climate Change

"The climate system is a complex, interactive system consisting of the atmosphere, land surface, snow and ice, oceans and other bodies of water, and living things…The climate system evolve in time under the influence of its own internal dynamics and due to changes in external factors that affect climate." (IPCC, 2007d) The natural greenhouse effect in one hand controls the amount of energy from the sun enters the atmosphere and absorbed by the Earth's surface. In the other hand, it also controls the amount of energy emitted from the Earth's surface could go through the atmosphere and enter the space. Thus the energy flow keeps the Earth's temperature stable and habitable (IPCC, 2007d; Karl & Trenberth, 2003). Changes in the balance of energy flow caused the climate change. Climate has changed naturally from time to time in the past due to, such as ice age eras and the warmth in the time of dinosaurs (IPCC, 2007d). However, human influences have been the dominant detectable influence on climate change over last 50 years, and lead to an unique circumstance (Karl & Trenberth, 2003).

Anthropogenic greenhouse gas emission is the main source of human influences on climate change. It changes the composition of atmosphere and enhances the greenhouse effect. The enhanced greenhouse effect traps more outgoing radiation from the Earth to space than it used be, results in a gradually increased temperature in Earth's surface and lower atmosphere. The global surface temperature has been observed to rise for 0.74℃ in the past hundred years, yet, it is projected to continuously raise for 1.8℃ by the end of 21th century compare to the end of 20th in the best scenario and 4℃ in the worst. The fact is commonly be referred to as "global warming" (IPCC, 2007d; Karl & Trenberth, 2003).

2.1.2. Effects of Climate Change

Several phenomena have been observed as the consequences of increased surface temperature (IPCC, 2007d). The thermal expansion of the oceans accompanied with the loss of land-based ice caused the rise of global sea level. According to IPCC's observation, the global sea level was rising with a rate around 1.7 millimetres per year in 20th century. It is projected to further rise by approximately 0.2 metres by the end of 21th century compare to the end of 20th in the best scenario and 0.6 metres in the worst scenario (IPCC, 2007d).

On the other hand, the amount, intensity, frequency and type of precipitation are influenced by warming temperature. Warmer climate enhanced the water-holding capacity of the atmosphere and increased the water vapour, led to more intense precipitation whilst total precipitation remains constant (Karl & Trenberth, 2003). The duration and frequency of precipitation may be shorter as it takes longer time to recharge the atmosphere with water vapour (IPCC, 2007d). In addition, the precipitation is more likely to falls as raining rather than snowing due to the raised temperature, especially at the beginning and the end of snow season (IPCC, 2007d). In the meantime, higher temperature tends to accelerate land's surface

drying and increase the likelihood of droughts. Thus, overall, warmer climate increases the risk of both drought (where it is not raining) and flooding (where it is raining) at different time and places (IPCC, 2007d).

Moreover, the increases in the intensity and duration of heat waves, tropical storm and hurricane have been recorded to increase since mid-1970. In spite of it remains uncertainty, the frequency and severity of such extreme events are expected to increase in the warmer future (IPCC, 2007d).

2.2. Mitigation and Adaptation

There are mainly two strategies to reduce the risks and vulnerability to the adverse impacts due to climate change among human society, namely mitigation and adaptation. Whilst mitigation aims to reduce human influences contribute to climate change (greenhouse gas emissions), adaptation seeks to adjust human society to minimize the climatic impacts (Swart & Raes, 2007). Occasionally, mitigation and adaptation are referred to as prevention and protection approaches (Dang, et al., 2003). In other words, "mitigation aims to avoid the unmanageable and adaptation aims to manage the unavoidable." (Laukkonen, et al., 2009)

Historically, mitigation and adaptation were treated as two fundamentally different strategies by both scientists and policy makers (Klein, et al., 2005; McEvoy, et al., 2006). The differentiation also reflected by the Woking Group division of the IPCC (Swart & Raes, 2007). It resulted in the mitigation-adaptation dichotomy (Biesbroek, Swart, & van der Knaap, 2009). Biesbroek, et al. (2009) explained the main reason is the differences in the way how knowledge was produced by the scientific community and used by policy makers in different periods of climatic research. Initially, climate change was perceived primarily as an environmental issue (Biesbroek, et al., 2009; Swart & Raes, 2007). The discussion was focused on the reality of global warming and the possible human footprint contributing to the change of temperature. Thus the attention was paid on how to mitigate the footprints, rather than how to adapt to the change even it was clear that adaptation strategies were needed (Biesbroek, et al., 2009). Only until recently, the attentions on adaptation were raised with the increased understanding and observations that a certain degree of climatic impact is unavoidable (Swart & Raes, 2007). Furthermore, it has been revealed by recent researches that even the most successful mitigation will not able to alter all the adverse climatic impacts in the long run. On the other hand, an unmitigated climate change would lead to a magnitude result to which adaptation is no longer possible or the economic and social cost would be extremely high. Thus both mitigation and adaptation are necessary to reduce the vulnerability and risks of climate change and variability (Klein et al., 2007).

2.2.1. Mitigation and the Greenhouse Gas Emission

Mitigation is defined in the IPCC Fourth Assessment Report as: "an anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases" (Klein, et al., 2007).

Carbon dioxide is the most important anthropogenic greenhouse gas (IPCC, 2007d). It accounted for more than 75% of total anthropogenic greenhouse gas emissions in 2004, primarily from the use of fossil fuels (Figure 2.1). Additionally, CO_2 contributes 25% of greenhouse effect in maximum (Karl & Trenberth, 2003). Other major anthropogenic greenhouse gases include CH_4 and N_2O (IPCC, 2007d). The emissions of greenhouse gases have increased by approximately 70% in the past three decades. CO_2 emission is the fastest increasing one, with growth of approximately 80%, whilst CH_4 and N_2O

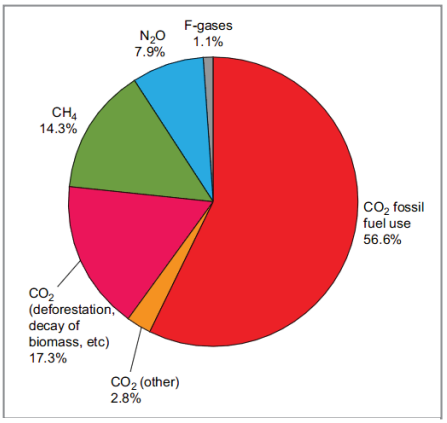

Figure 2.1 Global anthropogenic greenhouse gas emissions in 2004. Adopted from IPCC (2007b)

emissions have grown by 40% and 50% respectively (IPCC, 2007b). Figure 2.2 show the proportion of greenhouse gas emissions in 2004 by sector. One can see that the sectors which play important roles in the city area – energy supply, industry, transport and residential and commercial buildings accounted for 66.3% of total emissions. Yet, they are at the same time the largest growth sectors in terms of greenhouse gas emissions in the past three decades (IPCC, 2007b).

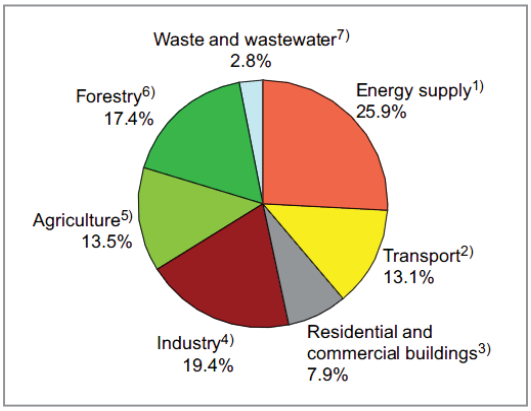

Figure 2.2 Greenhouse gas emissions by sector in 2004. Adopted from IPCC (2007b)

By its own definition, mitigation is therefore targeting at the major sources of the greenhouse gas emission. Common measures can be found are: price policies to discourage private vehicle usage in the transportation sector (Chapman, 2007), and the promotion of energy efficiency improvements and switching of fuels (IPCC, 2007b).

2.2.2. Adaptation and the Impacts of Climate Change

Adaptation means "adjustment in natural or human systems in response to actual or expected stimuli or their effects, which moderates harm or exploits beneficial opportunities" (Klein, et al., 2007). Whilst a number of researchers recognised a later attention on adaptation compare to mitigation, e.g. Klein, et al. (2005), Füssel (2007) and Swart and Raes (2007); Tol (2005) argued that adaptation is historical and pre-historical fact, as is adaptation to weather variability, thus it is incorrect to treat adaptation as something novel.

Whilst the effects of climate change have been reviewed in section2.1.2, the adaptation concerns more about how the effects impact on human society. For instance, the increased likelihood of drought will lead to shortage of food supply; the increased intensity of rainfalls will cause flooding in the low laying area; and the rise of average sea level will threat the coastal areas. The impacts are realised in different forms in different regions around the world (IPCC, 2007a).

Füssel (2007) has illustrated the diversity of adaptation activities. Adaptation is relevant for all climate-sensitive sectors, e.g. agriculture, water management and public health. It is motivated by current and future (expected) climate impacts. It can be either autonomous or purposefully planned; and the planned adaptation can be reactive (after the impacts have been experienced) or proactive (before the impacts have occurred).

Numerous adaptation options have been implemented and documented. Few examples are: building of dikes, which is adapting to the threat of river-level rising driven by intense rainfall or snowmelt in the upstream (de Bruin, et al., 2009); and construction of green roofs for cooling the buildings and reducing urban heat island effect (Wilson & Piper, 2010).

2.2.3. Differences between Mitigation and Adaptation

"Mitigation and adaptation are very different in what they mean and how they work" (Wilbanks, 2005). Klein, et al. (2005) have identified three key differences between adaptation and mitigation. The first difference is related to the spatial and temporal scales on which they effective. Whilst mitigation usually benefit globally and only evidenced in decades, adaptation typically works on the local or regional scale and effect immediately.

The second difference is the extent to which their cost and benefit can be determined, compared and aggregated. In spite of the diversity of mitigation options, they all serve to reduce greenhouse gases emissions. Therefore mitigation options can be easily compared in terms of emission reduction and certain monetary cost. Conversely, the benefits of adaptation are much more difficult to express in single metric, which can be measured in terms of property losses avoided or human lives saved (Klein, et al., 2005).

The last, the actors and types of policies involved in their implementation are different. Compare to adaptation, the number of sectoral actors involved in mitigation is limited, primarily transportation, energy and forestry sectors. In addition, they are generally well organised and used to taking long-term investment decisions. In contrast, the actors involved in adaptation represent a wide variety of sectoral interests, and the decisions are taken at different level, ranging from individuals to national planning agencies (Klein, et al., 2005).

2.2.4. The Tendency: Integration of Mitigation and Adaptation

Other than seen mitigation and adaptation as substitute for each other, and keep them as separate tools (Tol, 2005), there is a mainstream towards to explore the possibility to combine both strategies through different instruments. In the mean time, IPCC (2007c) suggested that in long term perspective, mitigation and adaptation should be implemented as complementary strategies. The main reason to combine both strategies is that both mitigation and adaptation strategies have been recognised as necessity and needed to be implemented as the same time (IPCC, 2007a; Klein, et al., 2005). In addition, mitigation and adaptation are closely linked. Both mitigation and adaptation are aim at reducing negative climate impacts, more mitigation may requires less adaptation and vice versa (Swart & Raes, 2007). "This raises the question of whether an integrated approach could offer benefits over two independent, parallel strategies…" (Swart & Raes, 2007)

Yohe and Strzepek (2007) have examined the complementary ability of both strategies by a hydrologic modelling approach with six non-implausible scenarios for Brahmaputa and Ganges Rivers in India. The authors concluded that while the climate change produce smooth, monotonic and manageable effects, a mitigation policy should increase the ability of adaptation policies; conversely, in the case of climate change produce variable impacts over time, mitigation might make adaptation less productive or even fail.

Klein, et al. (2005) argued climate policies could play a role to facilitate successful integration and implementation of sectoral mitigation and adaptation and development policies, and further brought up three questions for future researches. Biesbroek, et al. (2009) explained the significant potential of spatial planning to combine mitigation and adaptation. Swart & Raes (2007) proposed five ways to develop linked mitigation and adaptation strategies, namely avoid trade-offs, identify synergies, enhance and apply response capacity, develop institutional links and mainstreaming.

However, the complexity of the interaction between mitigation and adaptation is impeding such effective and successful integration. Wilbanks & Sathaye (2007) explained that the lack of information, capacities and policymaking are the main challenging to achieve the goal. Laukkonen, et al. (2009) argued that we need new tools, methodologies and procedures to formulate and implement the best solutions. Moreover, Biesbroek, et al. (2009) purposed that traditional administrative structure would not be able to solve the issue sufficiently.

2.3. Methods to Identify Synergies and Conflicts at City Level

2.3.1. Mitigation and Adaptation at the City Level

Although mitigation and adaptation policies can be implement in different levels, concrete mitigate as well as adaptive measures are most likely to act at local level coherently (Swart & Raes, 2007). In addition, urban environment is the place most of the population is concentrated and the impact is likely to be most keenly felt (McEvoy, et al., 2006). Thus there is a higher possibility to facilitate effectively integrated mitigation and adaptation in local context (Ayers & Huq, 2009; Biesbroek, et al., 2009).

Better understanding of the linkages between mitigation and adaptation measures would be valuable for forming an integrated climate policy (McEvoy, et al., 2006). In addition, identifying synergies is a way to help in developing integrated mitigation and adaptation strategy (Swart & Raes, 2007). However, there are merely a few literatures investigate into the synergies and conflicts between mitigation and adaptation (Hamin & Gurran, 2009), even though it is plausible the trade-off between mitigation and adaptation may be more commonplace than synergies (McEvoy, et al., 2006).

2.3.2. Diverse Approaches to Identify Synergies and Conflicts

Among current literatures, different approaches can be found for exploring the synergies and conflicts between mitigation and adaptation measures. Two major categories can be identified, namely documentary analysis and literature review, and multi-criteria analysis. However, it is worth to note that not all the literatures in the same category are exactly employing the same method whilst some of literatures do not actually aim at identifying the linkages between mitigation and adaptation; for instance, one of the literatures employed multi-criteria method is actually assessing a list of adaptation measures but it takes the ancillary benefits to mitigation into account for the evaluation.

2.3.2.1. Documentary Analysis and Literature Review

Swart and Raes (2007) summarised numerous measures and categorised in three types: actions not only decreasing greenhouse gas emissions but decreasing vulnerability to climate change (synergies), actions decreasing greenhouse gas emissions but increasing vulnerability to climate change (trade-off of mitigation), and actions decreasing vulnerability to climate change but enhancing greenhouse gas emissions (trade-off of adaptation). The authors then present the result in a table to support their arguments for integration of mitigation and adaptation.

Hamin and Gurran (2009) reviewed U.S., Australian and few international practice which is related to climate change in the field of land-use planning, and categorise the identified practice as adaptive or mitigating. A determination was made as to whether the action could create negative outcome for the alternative goal - mitigation or adaptation. The review covered several sectors including environment, housing, infrastructure, transport, economy, and community wellbeing. The authors concluded that a typical conflict is that while many adaptation actions require more open space or less dense built environment for storm water management and urban cooling, mitigation actions tend to create a high dense city to discourage vehicle trips. Furthermore, half of identified actions contain potential conflicts to achieving adaptation and mitigation simultaneously.

2.3.2.2. Multi-criteria Evaluation

Dang, et al. (2003) have conducted a multi-criteria analysis to assess the priority of mitigation and adaptation options in the national level with the case of Vietnam. The authors employed “adaptation benefits” as one of several criteria to assess mitigation options and “avoided greenhouse gas potential” for adaptation options. Similarly, de Bruin et al. (2009) also conducted a multi-criteria analysis to rank Dutch adaptation options national wide which included “mitigation effect” criterion.

In addition, Roy (2009) identified the relevance from several sustainability indicators to mitigation and adaption goals. The indicators were used to evaluate two land-use scenarios which were part of Dhaka Metropolitan Development Planning Support System (DMDPSS). The author then emphasized the potential use of DMDPSS in addressing both climate change mitigation and adaptation in cities in the conclusion.

2.3.3. New Method to Explore Synergies and Conflicts: Fuzzy Cognitive Mapping

Fuzzy cognitive mapping is a tool to depict human perception of a given system in a understandable way (Isak et al., 2009; van Vliet, Kok, & Veldkamp, 2010). It is especial suitable to generate knowledge from different experts in different discipline as several fuzzy cognitive maps can be superimposed into one single fuzzy cognitive map which is representing entire picture of one system (Kosko, 1988; Özesmi & Özesmi, 2004). With a combined map, hidden patterns in the system which are not perceived by individuals will emerge (Cole & Persichitte, 2000; Kosko, 1986). In addition, it is a semi-quantified conceptual model (Isak, et al., 2009; Kok, 2009), and a powerful tool to improve the understanding of how the studied system behave (Isak, et al., 2009). Refer to the aim of this research, fuzzy cognitive mapping can be a useful tool to improve the understanding of how mitigation and adaptation act, and there by identify the inter-links in between.

2.4. Fuzzy Cognitive Mapping

Fuzzy cognitive maps originate from the "cognitive maps" introduced by Axelrod in 1976 which were based on bidirectional diagram; Kosko then applied fuzzy logic to the connections and therefore "fuzzy cognitive maps" (Kosko, 1986). Fuzzy cognitive mapping is a modelling technique that follows an approach similar to human reasoning and decision-making process (Furfaro, Kargel, Lunine, Fink, & Bishop, 2010). It is especially suitable for analysing and depicting human perception of a given system (Isak, et al., 2009).

The strongest point of this method is its ability to highlight important but difficult to quantified factors and their casual relationships in a given system. Moreover, it is a relatively quicker and easier method to acquire information from different knowledge sources for data poor situations, e.g. local people or experts from different disciplines (Özesmi & Özesmi, 2004).

However, it is important to understand that the emphasis of concepts and strength of the casual relationships drawn in a fuzzy cognitive map is representing the perceptions from its authors, but not the real state of the given system (Ozesmi & Ozesmi, 2004).

2.4.1. Components of Fuzzy Cognitive Maps

Figure 2.2 shows an example of fuzzy cognitive map in graph form. The main components of a fuzzy cognitive map are:

- Concepts: represent the key drivers, factors or variables of the modelled system (Isak, et al., 2009; Kok, 2009);
- Connections: represent the causal relationships between concepts with a degree of causality. The causality can be described in linguistic values as strong, medium or low with a positive or negative sign, or as real numbers between -1 and +1 (Furfaro, Kargel, Lunine, Fink, & Bishop, 2010; Özesmi & Özesmi, 2004); and

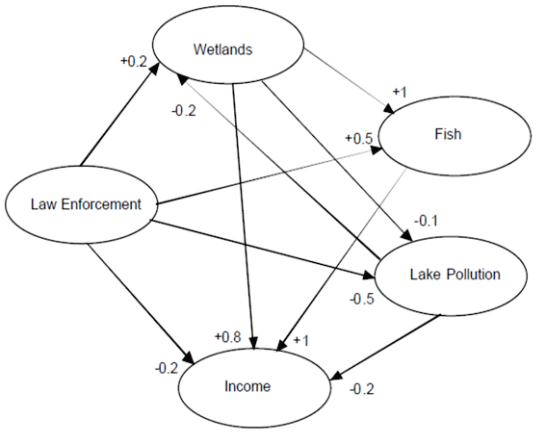

Figure 2.3 Example of fuzzy cognitive map. Adopted from Özesmi and Özesmi (2004)

- Adjacency matrix: contains all the relationships in a matrix form and usually used to perform calculations and analyses (Kok, 2009).

2.4.2. Fuzzy Cognitive Map Indices

In some cases, fuzzy cognitive maps can be complex as they are made up of large number of concepts which many inter-connections and feedback loops (Özesmi & Özesmi, 2003). However, graph theory indices provide a way to analysis the structure of the maps (Özesmi & Özesmi, 2004). First the frequency of a certain concept is mentioned can be counted. Whilst a concept is mentioned many times by the informants, it can be interprets as a important factor in the system (Isak, et al., 2009). On the other hand, the number of concepts and the number of connections in a map can be used to measure the density of the map. The map density is an index of connectivity (Özesmi & Özesmi, 2004). Higher map density indicates more causal relationships are perceived in the fuzzy cognitive map (Isak, et al., 2009). The density index can be calculated as below (Özesmi & Özesmi, 2004):

$$\text{Map density} = \frac{\text{number of connections}}{(\text{number of concepts})^2}$$

Equation 2.1

The concepts in a map can be further classified as transmitter, receiver or ordinary. They are defined by the outdegree and the indegree of certain concept. Whilst the outdegree is the sum of the strength values of the connection exiting the concepts, the indegree is the sum of the strength values of the connections entering the concepts (Özesmi & Özesmi, 2004). The transmitters are the concepts have zero indegree and positive outdegree - which means they effect other concepts without be effected; and the receivers are the concepts have zero outdegree and positive indegree – effected by others but not effecting other concepts; and the ordinary concepts contain both indegree and outdegree (Isak, et al., 2009; Özesmi & Özesmi, 2004). A high number of transmitters in a map indicates the system is influenced by many factors; and a high number of receivers in a map means the system results in many outcomes and implications (Özesmi & Özesmi, 2004).

2.4.3. Application of Fuzzy Cognitive Mapping

Fuzz Cognitive Mapping has been used to model a variety of topics in several disciplines (Özesmi & Özesmi, 2004). In social science, Cole & Persichitte (2000) applied FCM to model the determinants for the use of distance education; Tsadiras, Kouskouvelis, and Margaritis (2003) used FCM to analysis the political conflict in Albania to support the decision making; and Nasserzadeh, Jafarzadeh, Mansouri, and Sohrabi (2008) have employed FCM to model customer satisfaction for bank management. Furthermore, FCM has been used to model ecological scenarios (Kok, 2009; Özesmi & Özesmi, 2004), and water management scenarios (Giordano, Passarella, Uricchio, & Vurro, 2005; van Vliet, et al., 2010). In addition, Furfaro, et al. (2010) have developed a FCM for identifying cryovolcanism on the planet Titan.

3. RESEARCH METHODOLOGY

This chapter presents the methodology applied in the research. The first section outlines the structure of the research and the roles of each investigation in the research. The rest parts of the chapter describe the details of the methods used for investigations section by section.

3.1. Structure of the Research

This research was designed to use a combination of three methods to extract knowledge from three perspectives: academic perspective, practical perspective, and the perspective of citizen's perception (based on conceptual framework; section 1.5). Three investigations are formed to study from the three perspectives respectively (Figure 3.1):

- Investigation A: Synergies and Conflicts between Mitigation and Adaptation (academic perspective);
- Investigation B: Mitigation and Adaptation Practice in Rotterdam (practical perspective); and
- Investigation C: Perception of Mitigation and Adaptation (perspective of citizen's perception)

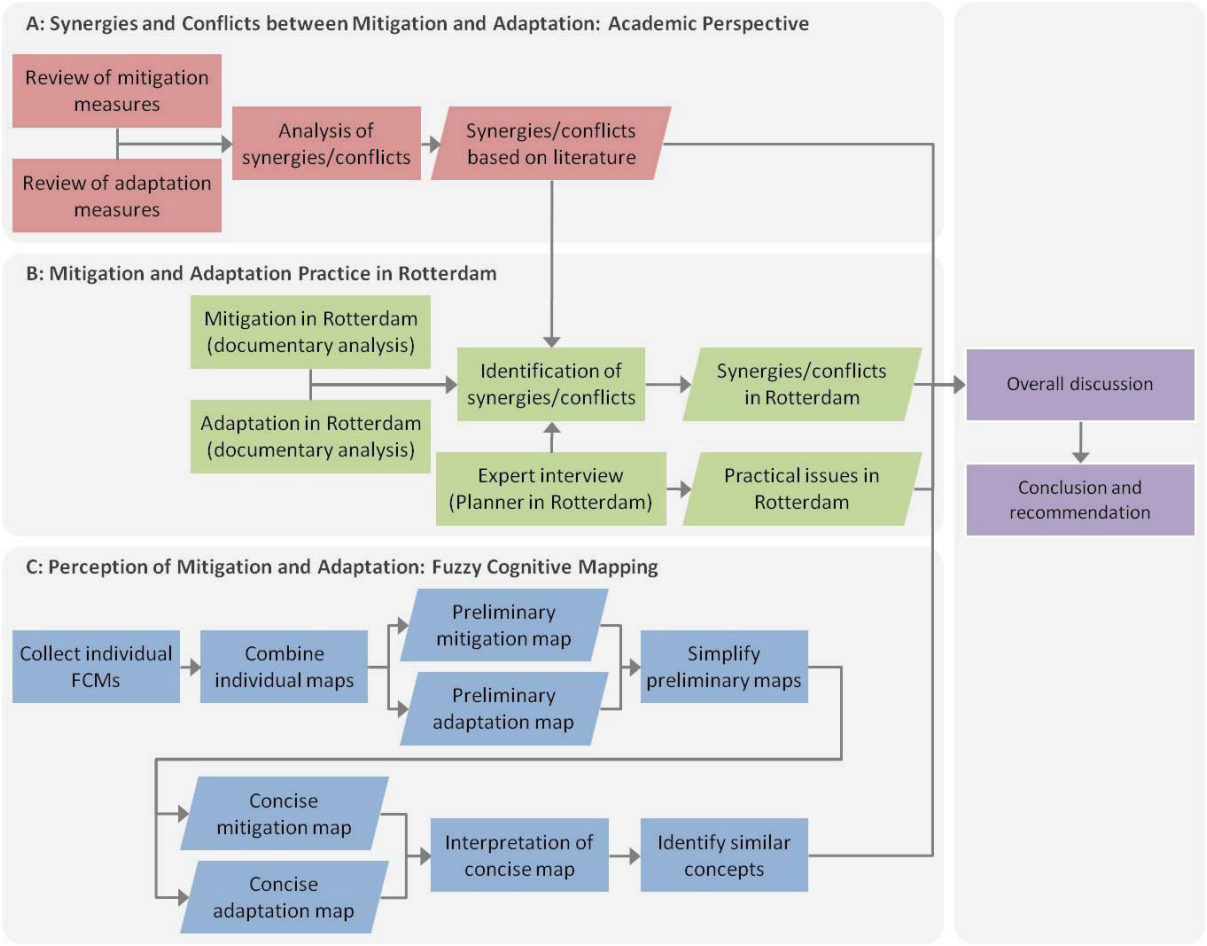

Figure 3.1 Research structure

Whilst investigation A aimed at building the basis of this research from literatures in terms of synergies and conflicts between mitigation and adaptation, the other two investigations aimed at exploring supplementary findings from other perspectives to strengthen the finding of the first investigation. In

addition, the practical issues which gained by planner whilst developing and implementing mitigation and adaptation plans were expected to be found in the case study of investigation B. In the end phase, the findings of three investigations were discussed in terms of complementarities of studying synergies and conflicts from different perspectives. The methods applied in three investigations were also being examined in the end stage.

3.2. Investigation A: Synergies and Conflicts between Mitigation and Adaptation

The method used in investigation A was inspired from Hamin and Gurran (2009) who firstly reviewed the mitigation and adaptation measures in the land use planning in the US and Australia, and secondly analysed these measures and found out the potential conflict. The two step set-up was adopted in this investigation. The first step was to review the mitigation and adaptation measures from literatures; and the second step was to analyse and identify the synergies and conflicts based on the measures derived from step one.

3.2.1. Review of Mitigation and Adaptation Measures

In the first step, a number of literatures including text book chapters, scientific reports and journal papers which have listed introduced, assessed or recommended the measures of mitigation and adaptation are reviewed to extract a list of common measures. The measures in five sectors which play important roles in the urban area were included: energy sector, water management, transportation, physical planning and the building sector. This research intended to focus on the scope of urban areas, therefore the industry and agriculture - which are normally situated in the rural area or in independent clusters outside the urban - were excluded even though these two sectors also contribute the driving forces of climate change and are affected by it. The main purpose in this step was to find out the objectives of mitigation and adaptation measures in each sector.

3.2.2. Analysis of Synergies and Conflicts

The second step was to analysis the measures which have been derived from literatures in step one. Further to identify which measures could potentially create synergies between mitigation and adaptation, and which may potentially cause conflicts. The determinant of synergies or conflicts was based on the objectives of mitigation and adaptation measures found in the last step. Measures were categorised to be synergistic whilst a certain measure on one aspect (mitigation or adaptation) can contribute benefits to the objectives on the other aspect (adaptation or mitigation); or to be categorised as conflicting whilst the certain measure may be counterproductive to the other aspect. However, neutral measures might be found is the certain measure does not benefit or counterproductive to the other aspect.

3.3. Investigation B: Mitigation and Adaptation Practice in Rotterdam

Rotterdam was chose to be the case study area of investigation B because it is currently implementing mitigation programme (Rotterdam Climate Initiative) as well as adaptation programme (Rotterdam Climate Proof). The investigation was designed with three steps. Firstly, the documents of mitigation and adaptation programmes were analysed to gain an insight into what mitigation and adaptation measures are planned in Rotterdam City. Secondly, an identification of synergies and conflicts of these measures was carried out. The last, expert interview was planned to be conducted to understand what synergies and conflicts have been seen by the city planners, and what issues they have met during planning and implementation phases.

3.3.1. Documentary Analysis of Mitigation and Adaptation Measures in Rotterdam

The procedure of this step was similar to the first step of investigation A. However, the sources from review the measures were the official brochure of mitigation and adaptation programmes in Rotterdam (Climate Office, 2010a, 2010b). The measures in the five sectors – energy sector, water management,

transport, urban spatial planning and the building sector – were included in the analysis. A list which provided an overview of mitigation and adaptation measures was then prepared for the next step.

3.3.2. Identification of Synergies and Conflict between Mitigation and Adaptation Measures in Rotterdam

In this step, the synergies and conflicts between the measures which were derived from last step were found. However, the determinants of synergies and conflicts were based on the finding of investigation A. The purpose was to build a comparable list or synergistic and conflicting measures in Rotterdam, and further to find out what synergies and conflicts have been recognised by city planners – which were expected to be found out from the expert interview – and which have not yet been recognised.

3.3.3. Expert Interview

The expert interview was conducted to gain knowledge from the practical point of view. One main objective of the interview was to find out whether the city planners realised that some of the mitigation and adaptation measures can actually create synergies and some cause the conflicts. What they have seen were then compared to the result of last step to find out what they have not seen. The second objective was to find out whether there were barriers or difficulties that impeded the implementation of these mitigation and adaptation measures.

3.4. Investigation C: Perception of Mitigation and Adaptation: Fuzzy Cognitive Mapping

In the investigation C, the method of fuzzy cognitive mapping was applied to extract information from people in terms of how do they perceive mitigation and adaptation. The aim was to generate two maps representing mitigation and adaptation systems respectively by combining individual perception maps, and further to find out the linkages between these two maps in terms of synergies and conflicts. The following sections discuss the processes of how the perception maps were collected and how the individual perception maps were combined into the complete mitigation and adaptation maps.

3.4.1. Collect Individual Fuzzy Cognitive Maps

Fuzzy cognitive maps can be collected mainly through four ways: (1) from questionnaires, (2) by extraction from written texts, (3) by drawing them from data that shows causal relationships, and (4) through interviews with people who draw them directly (Özesmi & Özesmi, 2004). However, in terms of interview, different set-up can be found, for instance, interview with stakeholders or experts individually (Nasserzadeh, et al., 2008; Özesmi & Özesmi, 2003), or in a group brainstorming session (Cole & Persichitte, 2000; van Vliet, et al., 2010).

This investigation used the method that letting the participants draw the maps directly in a group session, but the communication between participants were asked to be restricted. Totally 22 participants in the University of Twente, Faculty of ITC were invited. The participants were experts in different dimensions of urban planning and representing the experiences from different countries. In the beginning of the group session, an introduction on the cause of climate change, the impacts of climate change, the roles of mitigation and adaptation, the method of fuzzy cognitive mapping and the purpose of the brainstorming session was presented to the participants. Then the participants were asked to draw two maps according to the questions one by one. The time for drawing the maps were limited in 20 minutes for one map.

For the mitigation map, the question: "Referring to your home city/country, how you think of 'greenhouse gases emission'?" was asked for the participants to draw their individual fuzzy cognitive maps. For the adaptation map, a list of climate impacts was provided in advance and the question: "Please choice one of the impacts, and referring to your own city/country, draw a fuzzy cognitive map." Three steps were asked to be followed whilst for the participants to draw the maps (Kok, 2009; Özesmi & Özesmi, 2004): (1) List the concepts – firstly list all the concepts that come up in participants' mind when they see

the questions and put the concepts in the middle of the paper; (2) Draw connections – draw the connections between those concepts the participants think a causal relationship appear, and give a sign (+ or -) to show the correlation of certain connection (positive or negative); and (3) Weight connections – weight the connections with five levels (very strong, strong, medium, weak and very weak). The drawing process was end when the participants felt finished or when the time is up.

3.4.2. Combine Individual Maps

The individual fuzzy cognitive maps collected from the group session were eventually combined into two maps (preliminary maps), with one for mitigation and one for adaptation. The process of combination was simply adding all the concepts mentioned by participants into the same map (Kosko, 1988). However, the wording for the same concept maybe differs from one participant to another. Coding the concepts and using a unified terms were necessary. For instance, whilst the concepts "Increase of average temperature" and "Temperature rise" were referring to the some meaning, they were then coded into "Increased average surface temperature".

With respect to the combining of connections, the linguistic weightings were first transformed into numeric form (very strong = 0.9, strong = 0.7, medium = 0.5, weak = 0.3 and very weak = 0.1). Then the Equation 3.1 was used to generate the new weighting in the combined map (Kosko, 1988). It is worth to note that, by applying this equation, the weightings of all the connections – including the connections which were mentioned by only one participant – were divided by the total amount of the maps to sum up the new weighting for combined maps. The advantage of applying this equation to generate the new weighting is that not only the strength of the connection but the frequency a certain connection was mentioned were taken into account. Thus the strongest and most mentioned connections were able to be highlighted in the combined maps.

$$\text{the weighting in combined map} = \frac{\text{sum of the weighting in individual maps}}{\text{total number of individual maps}}$$

Equation 3.1

3.4.3. Simplify Preliminary Maps

By applying the process mentioned in the last section, it is however easily result in complex maps with many concepts and connections which are difficult to make sense. Maps with over 20-30 concepts start being counterproductive for gaining insights (Özesmi & Özesmi, 2004). Therefore the maps were further processed by a simplification procedure. The simplification can be done by aggregating the concepts or by erasing the weak connections (Özesmi & Özesmi, 2004). This research used two steps to simplify the preliminary maps and therefore generated the "Concise mitigation map" and "concise adaptation map":

(1) Keep the connections which were perceived as strong by more than two participants, and the connections which were perceived as very strong by at least one participant;
(2) Erase the concepts which became unconnected after removing the weak connections in the first step.

3.4.4. Interpretation of Concise Maps

Many studies analysed the structure of the maps by interpreting the fuzzy cognitive map indices such as outdegree, indegree, most central concepts and most mentioned concepts (Özesmi & Özesmi, 2003; van Vliet, et al., 2010). However, this research tended to include visual interpretation whilst it is a rather direct way to communicate the output. Furthermore, how the concepts are connected together is something that cannot be shown by simply analyse the indices.

3.4.5. Identify Similar Concepts

By comparing both concise mitigation and adaptation maps, the similar concepts were expected to be found. However, the linkages in terms of synergies and conflicts between the mitigation adaptation maps generated in this investigation were sparse; the possible reason will be discussed in chapter 6.

3.5. Overall Discussion

In the end phase of this research, the findings from three investigations were brought together for comparison. First, an overall comparison was made to present the final finding in terms of synergies and conflicts between mitigation and adaptation. Second, a cross-perspective comparison was presented to discuss the cross relationship between different perspectives (Figure 3.1). The findings of practical perspective can be used to test the practicability of the findings from academic perspective; at the same time, the result from the practical perspective can also be used to cross check whether it is acceptable with respect to the opinions from citizens' point of view; the last, the comparison between academic perspective and citizens' perception can reveals that whether the focus of academic group relevant to the citizens. In addition, the methodological shortcomings will be discussed in the end.

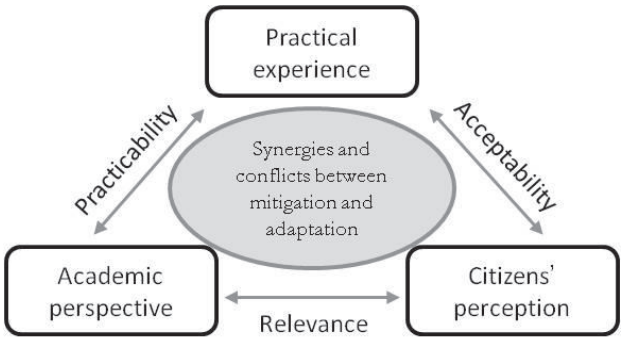

Figure 3.2 Diagram describing the relationship between three perspectives

4. SYNERGIES AND CONFLICTS BETWEEN MITIGATION AND ADAPTATION: ACADEMIC PERSPECTIVE

This chapter presents the findings of investigation A in this research. The first two sections summarise the mitigation and adaptation measures in five sectors according to the review of literatures. The second part identifies the synergies and conflicts between mitigation and adaptation measures based on the findings of first two sections and few conditions to create synergies or conflicts are found. The chapter ends with a discussion and conclusion where a key point is highlighted.

4.1. Sectoral Mitigation Measures

4.1.1. Mitigation Measures in Energy Sector

One of the most important objectives to mitigate greenhouse gas emission in the energy sector is to increase the efficiency of energy generation. It can be achieved by regulating the minimum efficient standard of power plant. A combination of tax deduction and fiscal incentives would encourage energy agencies to develop new generation of power generators in terms of better efficiency. In the long run, development in reliable renewable energy sources is necessary. However, it needs financial supports from government and progress in technology development (IPCC, 2007b).

Another objective is to reduce the energy consumption of end users. Common measures are to charge an electricity bill depends on actual consumption or a fixed charge for every user (Pearce & Harris, 2007), and incentives to encourage energy-saving actions (Liu, Liou, Yeh, & Shang, 2009). The purpose is to discourage the use of energy by increasing its monetary cost. In addition, improvements in energy efficiency and reduction of standby power consumption for household appliances will reduce energy consumption indirectly (Blok, 2005).

4.1.2. Mitigation Measure in Water Management Sector

Unlike adaptation, the amount of literature on the topic of mitigation in water management in the urban area is relatively less. The mitigation measures in this sector is primarily target at the greenhouse gases emission from inappropriate wastewater treatment or non-treatment (IPCC, 2007b). Feasibly options are: improved infrastructure and technology in wastewater treatment, and developing re-cycle and re-use facilities (IPCC, 2007b).

4.1.3. Mitigation Measures in Transport Sector

Usually an ultimate mitigation objective in the transport sector is to promoting a vast modal shift from motorized travel mode toward lower emission modes or zero-carbon modes, for instance, public transport, cycling and walking (Chapman, 2007; Marsden & Rye, 2010). To achieve the goal, several instruments are involved. In the short-term perspective, price policies such as road charges, emission charges, congestion charges, zone toll as well as parking tariffs are playing an important role. The main purpose is to increase the total cost of driving a private vehicle compare to the cost of utilising public transport (Chapman, 2007; Grazi & van den Bergh, 2008).

Another major objective to lower greenhouse gas emissions in the transport sector is to improve the vehicle technology. Introducing lightweight materials and designing smaller and streamline shape vehicles will reduce the energy requirement for moving vehicle forward (Chapman, 2007; Grazi & van den Bergh,

2008). In addition, invest in vehicles which using lower-carbon or renewable fuels would be feasible in long-run. However, the latter option would be relatively difficult since alternative types of fuel are often too expensive compare to fossil fuels (Chapman, 2007).

The other available options are: changing in the behaviour of using a car, such as ecological driving and carpool. In addition, promoting communications technology such as internet and video conferencing would reduce the trips whilst people can work at home instead of commuting (Chapman, 2007).

4.1.4. Mitigation Measures in Urban Spatial Planning Sector

Compactness, density and mixed land use are three of many concepts in designing sustainable urban form (Jabareen, 2006). The spatial distribution of people's activities such as work places, services and shops influences their travel behaviour in the long run. Designing a compact, denser city with mixed land use plan will shorten the distance of these types of travel destinations, and the demand of transport well be reduced; therefore the emissions from the transport sector are indirectly reduced (Grazi & van den Bergh, 2008; Jabareen, 2006).

Urban greening is another design concept of sustainable urban form. It improves the air quality as well as quality of life in the urban area (Jabareen, 2006). Additionally, appropriate greening plans in the residential area are suggested to indirectly reduce energy consumption for building cooling as well as heating purpose. The shading effect and evapotranspiration from vegetations help in reducing air temperature therefore the cooling demand decreases (yet, wrongly locating vegetations which block solar heat in the winter might increases the demand for heating). In addition, a group of trees scattered throughout neighbourhood reduces the wind speeds. Lower wind speed decelerates cold air infiltrating in to the buildings therefore the energy consumption for heating can be reduced (Jo & McPherson, 2001). Other than the benefit of indirectly reduce energy consumption, an investigation in the US suggested that urban forest also helps in reducing carbon dioxide level directly. Whilst coverage of large and healthy trees in the city increased, the carbon storage and sequestration within the city generally increases, too (Nowak & Crane, 2002).

4.1.5. Mitigation Measures in Building Sector

As one of the energy end-users, mitigation measures in the buildings sector are primarily aiming at reduction of energy consumption in the daily operation. One of practicable measures is the usage of energy efficient appliances in the household buildings such as televisions, refrigerators, lights, air-conditioners and cook stoves (Ürge-Vorsatz & Novikova, 2008). In addition, the installation of well-designed heating equipments also helps in reducing energy consumption; examples are: heating control system, district heating system and bedrock heat pumps (Gustavsson, Joelsson, & Sathre, 2010; Ürge-Vorsatz & Novikova, 2008).

Other measures are related to the designing and the material of the buildings. Better interior designing of the building can improve the operation efficiency of heating and cooling systems (Ürge-Vorsatz & Novikova, 2008). In terms of building material, the buildings with wood frames are suggested to consume less energy compare to concrete frames from the life-cycle perspective (Börjesson & Gustavsson, 2000); the other examples of energy-consuming material of modern buildings - which are suggested to be avoided - are: aluminium, ceramic and vinyl tiles (Dimoudi & Tompa, 2008).

Better operation plan and using behaviour will support in cutting energy consumption, for instance, reduction of energy consumption whilst the building is not in use (Blok, 2005), and introduction of efficient light control systems (Ürge-Vorsatz & Novikova, 2008). Furthermore, the choice construction practice also largely decides the embodied energy when a building is constructed (Dimoudi & Tompa, 2008).

4.2. Sectoral Adaptation Mesures

4.2.1. Adaptation Measures in Energy Sector

One of the major concerns over adaptation in energy sector is the increased energy demand on the cooling system due to increased temperature (de Lucena, Schaeffer, & Szklo, 2010; Ruth & Lin, 2006). Thus modification in existing energy supply facilities to increase capacity is suggested to meet the future demand. On the other hand, adjustment in energy price would signal to the consumers to reduce the energy use (Ruth & Lin, 2006).

The other concern over adaptation in this sector is the reduced productivity of climate-sensitive power generation, for instance, marine energy (Harrison & Wallace, 2005) and hydroelectricity (de Lucena, et al., 2010). The solution is to expend the share of energy supply in other types of energy sources, for instance, thermal powers (e.g. coal-fired, gas turbine and nuclear power) (de Lucena, et al., 2010) and renewable energy sources (e.g. solar power and wind power) (Awuor, Orindi, & Adwera, 2008). In addition, developing diverse sources instead of rely on rather single energy source will increase the resilience of the energy supplying system under the changing climate (IPCC, 2007a).

The last adaptation focus in energy sector is to strengthen the energy supplying infrastructure to confront with extreme weathers such as intense rainfalls and storms; for instance, strengthening overhead energy transmission and distribution infrastructure, and installing underground cables (IPCC, 2007a).

4.2.2. Adaptation Measures in Water Management Sector

Actions to protect human settlement from water threats can be found through history (Muller, 2007). Overflowing of rivers is one of the major concerns, measures like river training, flood diversion canals (Muller, 2007), flood protection embankments (Alam & Rabbani, 2007) and dikes (Birkmann, Garschagen, Kraas, & Quang, 2010) are adopted to overcome this issue. With respect to coastal cities, the rising sea level is another water-related issue. Constructions such as seafront wall, beach defences, breakwaters and groynes are implemented to prevent the inundation by the sea as well as coastal erosion (Dossou & Glehouenou-Dossou, 2007). The other flood proofing measures are: expansion and construction of storm water drainage system (Muller, 2007), and other flood control structures (e.g. sluices and pumping stations) (Alam & Rabbani, 2007)

4.2.3. Adaptation Measures in Transport Sector

The consequences of climate change for the transport sector is likely receiving relatively less attention (Koetse & Rietveld, 2009); another observation revealed that adaptive activities in transport sector in UK are less than other sectors (Tompkins et al., 2010). However, few adaptation objectives for this sector are suggested by researchers. The first objective is to revise the design parameters of transport infrastructure to accommodate the impacts of climate change; for instance, the height standard of bridges, elevation and location of coastal and riverside roads (Regmi & Hanaoka, 2011). In this sense, parts of existing transport infrastructures would need to be retrofitted (Cochran, 2009). The other objective is to choice appropriate construction materials; for instance, the use of different grades of bitumen to overcome increased temperature, and the selection of porous aggregates to facilitate drainage (Regmi & Hanaoka, 2011).

4.2.4. Adaptation Measures in Urban Spatial Planning Sector

In terms of reducing and adapting to urban heat island effect, urban green features are suggested for developments in the built environment (Birkmann, et al., 2010; Wilson & Piper, 2010). Green spaces such as parks and street tree covers would not only help in heat issues but enhance the amenity value within the urban area (Wilson & Piper, 2010). For the desert and tropical regions where the daily average temperature may exceeds 30℃ in the summer, changes in urban form such as additional indoor,

underground and semi-outdoor spaces might be necessary whilst it will be unpleasant to stay in outdoor spaces and parks under a such high temperature (Shimoda, 2003).

With respect to the flooding issue, changes in urban layout are recommended; for instance, land use restrictions in the high risk areas, redeveloping and raising the low laying areas, and forced relocation of settlements if necessary (Birkmann, et al., 2010). The other measure is to design multi-functional public (waterfront) open spaces which operate as parks or green spaces in normal time, but functions as storage basin during extreme wet period (Roggema, 2009).

4.2.5. Adaptation Measures in Building Sector

Two types of adaptation measures can be found in this sector. The first type is to adapt to increased temperature and urban heat island effect. One method is to increase the efficiency of cooling equipments inside the building; however, thermal insulation of the building is needed to reduce the demand of cooling (Shimoda, 2003). On the other hand, installation of green roofs, garden roofs and/or green walls is recommended to help in cooling the building and reduce the heat island effect. In the meantime, the greens also improve storm water attenuation (Wilson & Piper, 2010), which reduces the incidence of flooding due to intense precipitation.

Another type of adaptation measures in the building sector is to reduce the flood impact on the buildings which are situated at the bank of rivers or the low laying areas. One common way is to elevate the foundation of buildings to a safety range (Birkmann, et al., 2010). The other way is to increase the flexibility of the buildings on the riverside; for instance, buildings which could storage water in the basement or ground floor during sever flood, or floatable buildings (Roggema, 2009).

4.3. Potential Synergies and Conflicts between Mitigation and Adaptaion

In the second step of Investigation A, the measures which have been reviewed in the last two sections are then further examined in order to identify which measures can potentially create synergies, and which might potentially cause conflicts. The determinant of synergies or conflicts is based on two situations:
Measure potentially creates synergy: a certain measure in one aspect (mitigation/adaptation) can potentially contributes benefit to the objectives of the other aspect (adaptation/mitigation); and
Measure potentially causes conflict: a certain measure in one aspect is potentially counterproductive to the objectives of the other aspect.

Table 4.1 summarises the measures and the identification of synergies and conflicts. Three specific conditions for a certain measure being synergistic and two conditions for conflicting were found. They are respectively:

- **Measure potentially creates synergy:**
  [a]Reducing Energy Demand and/or Consumption
  [b] Developing Renewable Energy Sources
  [c] Promoting Urban Greening
- **Measure potentially causes conflict:**
  [d] Increasing the Consumption of High Emission Energy Source
  [e] Densification of Built Environment

Each of these conditions is described in the following sections.

Sectors	Mitigation Measures	Adaptation Measures
Energy	● Efficient regulation for energy generation plants (IPCC, 2007b) ● Monetary incentives to encourage efficient energy generation (IPCC, 2007b) ● **Energy consumption charges** (Pearce & Harris, 2007) ● **Promoting energy-efficient household appliances** (Blok, 2005) ● **Promoting energy-saving actions** (Liu, et al., 2009) ● **Development in renewable energy sources** (IPCC, 2007b)	● **Changes in energy price to discourage energy demand** (Ruth & Lin, 2006) ● **Increasing generation capacity of existing facilities** (de Lucena, et al., 2010) ● **Expand energy share in non-climate-sensitive power generation** (de Lucena, et al., 2010) ● **Use of renewable energy sources** (Awuor, et al., 2008) ● Developing diverse energy supplying sources (IPCC, 2007a) ● Strengthening energy transmission and distribution infrastructure (IPCC, 2007a)
Water management	● improved infrastructure and technology in wastewater treatment (IPCC, 2007b) ● developing re-cycle and re-use facilities (IPCC, 2007b)	● River training and flood diversion canals (Muller, 2007) ● Construction of river embankments and dikes (Alam & Rabbani, 2007; Birkmann, et al., 2010) ● Construction of seaside defences (Dossou & Glehouenou-Dossou, 2007) ● Expansion and construction of storm water drainage system (Muller, 2007) ● Other types of flood control structure (Alam & Rabbani, 2007)
Transport	● Price policies (charges and taxes) to discourage private vehicle usage (Chapman, 2007; Grazi & van den Bergh, 2008) ● Improvement in vehicle technology (Chapman, 2007; Grazi & van den Bergh, 2008) ● Changes in vehicle using behaviour (Chapman, 2007) ● Promoting (internet) communication technology (Chapman, 2007)	● Revision of designing parameters for transport infrastructure (Regmi & Hanaoka, 2011) ● Retrofitting existing transport infrastructure (Cochran, 2009) ● Choices of appropriate construction material (Regmi & Hanaoka, 2011)
Urban spatial planning	● **Promoting compact denser, and mixed land use urban plan** (Grazi & van den Bergh, 2008) ● **Promoting appropriate urban greening plan** (Jo & McPherson, 2001)	● **Promoting urban green features** (Birkmann, et al., 2010; Wilson & Piper, 2010) ● **Additional indoor, underground, semi-outdoor spaces (in desert or tropical regions)** (Shimoda, 2003) ● Land use restriction in high risk areas (Birkmann, et al., 2010) ● Redeveloping and raising low laying areas (Birkmann, et al., 2010) ● Forced resettlements (Birkmann, et al., 2010) ● Designing of multi-functional public (waterfront) open spaces (Roggema, 2009)
Building	● **Utilisation of energy-efficient appliances** (Ürge-Vorsatz & Novikova, 2008) ● **Installation of well-designed heating system** (Gustavsson, et al., 2010; Ürge-Vorsatz & Novikova, 2008) ● **Promoting better interior designing** (Ürge-Vorsatz & Novikova, 2008) ● **Utilisation of energy saving building materials** (Börjesson & Gustavsson, 2000; Dimoudi & Tompa, 2008) ● **Promoting better building operation and using behaviour** (Blok, 2005; Ürge-Vorsatz & Novikova, 2008) ● Advance in construction practice (Dimoudi & Tompa, 2008)	● **Increase in the efficiency of cooling equipments** (Shimoda, 2003) ● **Building thermal insulation** (Shimoda, 2003) ● **Promoting green roofs and green walls** (Wilson & Piper, 2010) ● Elevated building foundation (Birkmann, et al., 2010) ● Designing of flexible riverside buildings (Roggema, 2009)
* This table summarises the mitigation and adaptation measures which have been review by this investigation. The identification of synergies and conflicts are highlighted by colours where green shows the measures potentially create synergies and the red ones potentially cause conflicts.		

Table 4.1 Summary of sectoral mitigation and adaptation measures

4.3.1. Conditions Let Measures Potentially Create Synergies

4.3.1.1. Reducing Energy Demand and/or Consumption

There are quite a few number of measures in this investigation were indentified to be synergistic because of this reason. The rising energy demand under changing climate will impact on the energy sector in terms of higher capital expenditure (Ruth & Lin, 2006). Therefore measures to discourage energy consumption or improve the energy usage efficiency are advocated to ease off the rising demand. However, from mitigation point of view, the energy consumption from end-users has already been seen as a major issue to cut down current greenhouse gases emission whilst the energy sector is one of the main emitters among human activities. Therefore these types of measures – which aim at reducing energy demand and consumption – are identified for contributing benefits to both mitigation and adaptation strategies.

4.3.1.2. Developing Renewable Energy Sources

Development in renewable energy sources such as wind or solar energy is suggested from both mitigation and adaptation perspectives. However, it is based on different motivations. From the mitigation point of view, it is focused on the potential that renewable energy sources might took over the energy sources which produce large number of greenhouse gases emissions (e.g. coal-fired and gas turbine) in the long run(IPCC, 2007b). Differently, the adaptation strategy emphasises on developing diverse energy sources to increase the resilience of energy supply system (IPCC, 2007a). Another view point considers diverse renewable energy supply, or "decentralised renewable energy", as a chance of utilising local resources for energy generation (e.g. bio-energy) to drive poverty alleviation and enhance adaptive capacity in less developed countries; therefore it achieves mitigation-adaptation nexus (Venema & Rehman, 2007).

4.3.1.3. Promoting Urban Greening

Urban greening measures include urban green covers and green roofs of the building. From the adaptation point of view, urban greens help in cooling down the built environment therefore reduce the impact of increasing temperature in the hot summer and the effect of urban heat island; in addition, urban greens also function as temporary water storage during storm events or sudden downpours (Wilson & Piper, 2010). From the mitigation point of view, whilst the entire built environment is cooled down, the energy demand for building interior cooling decreases at the same time. Furthermore, few researches discovered that urban greens can absorb and store surrounding carbon dioxide, thus directly reduce the concentration level in the atmosphere (Li et al., 2010; Nowak & Crane, 2002). Accordingly, it can be concluded that promoting urban greening can achieve both mitigation and adaptation objectives.

4.3.2. Conditions Let Measures Potentially Cause Conflicts

4.3.2.1. Increasing the Consumption of High Emission Energy Source

There were three adaptation measures identified to conflict with mitigation objectives: increasing generation capacity of existing facilities, expand energy share in non-climate-sensitive power generation, and additional indoor, underground and semi-outdoor spaces in desert or tropical regions (Table 4.1). However, it is depending on how certain measures will be implemented as well the local condition – the availability of renewable energy sources. The key point is that these measures might result in more usage on fossil fuels for energy generation. For instance, additional indoor, underground and semi-outdoor spaces will require more use of air-conditioning system – more energy consumption; and the expansion of existing energy generation capacity might increase the dependence upon fossil fuels if there has no other lower emission energy sources available.

4.3.2.2. Densification of Built Environment

Densification of built environment is one way to achieve mitigation in the urban planning as it influences inhabitants' travel behaviour and reduce the usage of private vehicles – less greenhouse gases emission. Yet, from the adaptation point of view, more open spaces and green spaces are required to adapt

increased temperature and urban heat island effect, in other words, lower density in the built environment. Therefore a conflict between the principle of mitigation and adaptation can be identified. This finding is in line with the conclusion made by Hamin and Gurran (2009) who then purposed a better urban form with moderate density and multi-functioned green spaces.

4.4. Discussion and Conclusion

The common measures and objectives of mitigation and adaptation in five sectors (energy, water management, transport, urban planning and building sector) have been reviewed in this investigation. Three conditions for measures being synergistic and two conditions for conflicting have been identified in this investigation. It is apparently that synergies and conflicts happen in the sectors which both mitigation and adaptation measures are highly concerned (energy, urban planning and building sector), and especially when the issue of energy consumption is involved.

On the other hand, one might see that whilst some of these reasons for determining measures being synergistic or conflicting are explicit, others are rather hypothetical (e.g. the reason [d] increasing the consumption of high emission energy sources; section 4.3.2.1). One key point is that the way the measures are built and implemented will ultimately determine whether the measures cause conflicts or not (Hamin & Gurran, 2009). For instance, if one wanted to reduce the dependence on climate-sensitive energy sources as an adaptation strategy in the energy sector, the solution could be to increase the use of coal-fired energy. It might be a financially feasible option, but eventually produced more greenhouse gases emission – conflict to mitigation objective. The other solution could be to develop the use of solar energy, which might be costly but created synergies to mitigation objective.

To conclude this chapter, this investigation has identified few conditions that can assess whether a certain mitigation or adaptation measure can potentially create synergies or potentially cause conflicts with a structured method. However, the assessment might be rather theoretical because of that the way the certain measure is built and implemented will ultimately determine whether the synergies can be created or conflicts may be induced.

5. CASE STUDY: MITIGATION AND ADAPTATION PRACTICE IN ROTTERDAM

This chapter presents the findings of the investigation B. The first section provides an introduction of the study area. The second section adopts national figures to illustrate the greenhouse gases emissions and the climate impacts in the city. The third part presents the analysis of the synergies and conflicts in Rotterdam. In the end of this chapter, the summary of the interview provides the insight of the practical issues in Rotterdam.

5.1. Study Area: Rotterdam

5.1.1. Location

Rotterdam is the second largest city and municipality in the Netherlands. It is situated in the province of Zuid-Holland in the western part of the country. Rotterdam is on the riverbanks of Nieuwe Maas River, one of the channels in the end of Rhine-delta (Figure 5.1). The municipality covers 319.35 km² in total (205.90 km² of which is land) (COS, 2009), including Rotterdam port and the city centre. Figure 5.2 show the satellite image of Rotterdam municipality where the city centre is on the riverbanks on the right end of the image (East), and the port area extends from the edge of the centre to the left (West) until the estuary of the river. It is worth to note that there is a large part of the city located few metres below the sea level; it places Rotterdam in the circumstance facing the increased threat of flooding in the changing climate.

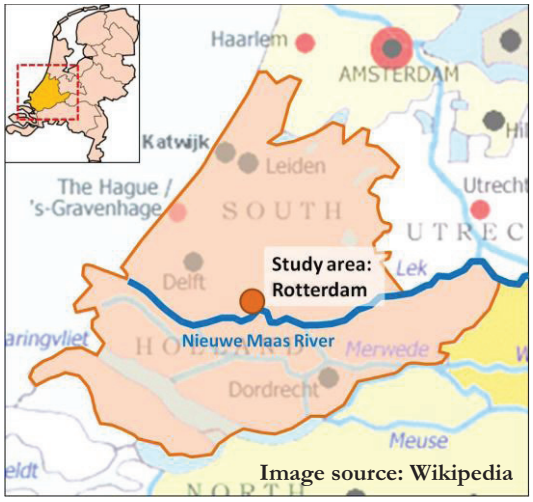

Figure 5.1 Location of Rotterdam

Figure 5.2 Satellite image of Rotterdam centre and the harbour (image source: Wikipedia)

5.1.2. Population

According to Centraal Bureau voor de Statistiek (2011), there were 593,049 inhabitants live in Rotterdam in the end of 2009, accounting for 3.6% of Dutch population. The population density is approximately 2,880 people per km² land area. Similar to other major Dutch cities, Rotterdam City has a relatively high proportion of inhabitants are non-native, of which is accounting for around 46% of total population (Table 5.1).

	Natives	Immigrants
Rotterdam	**54%**	**46%**
Amsterdam	51%	49%
Den Haag	54%	46%
Utrecht	69%	31%
Netherlands	**80%**	**20%**

Table 5.1 Proportion of natives and immigrants in major Dutch cities in 2008. Adopted from COS (2009)

Figure 5.3 shows the population variation in Rotterdam in the past two decades. After reaching the peak of 600,000 in 2002, the population started to drop whilst some of the citizens moved out from the municipality and settled down in the surrounding regions (Gemeente Rotterdam, 2008). However, the population grew again since 2007, because of the increased amount of immigrant inflows – which accounted for 49.3% of total growth in 2008 and 2009 – and the reduced inter-municipal outflows (data source: CBS, 2011).

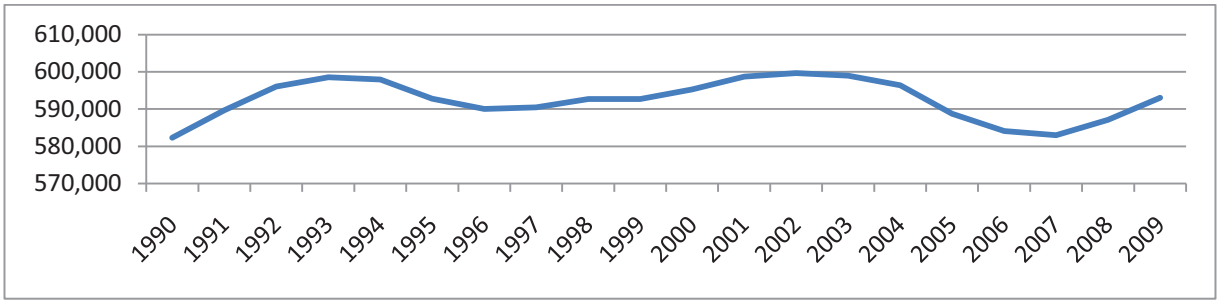

Figure 5.3 Rotterdam population variations between 1990 and 2009 (data source: CBS, 2011)

5.1.3. Economic

The economic structure of Rotterdam is built on four main parts: business services, the port with affiliated business activities, capital-intensive industries, and quaternary sector – the knowledge-based economy (Gemeente Rotterdam, 2008). Table 5.2 shows the share of employment by economic activities in four largest Dutch cities. The economic activities which share a higher proportion are highlighted by gray background. It is apparently that the economic activities of industry, utilities, construction, and transport and communications are indeed playing more important roles in Rotterdam's economy compare to other cities. Although business services accounts for almost one in five of total employments in Rotterdam, it has relatively less shares compare to other cities. In other words, this table reveals the economic characteristics of these cities: whilst Amsterdam is the financial centre and Den Haag is the governance centre of the Netherlands, Rotterdam City is more industrial-oriented.

Economic activities	Rotterdam	Amsterdam	Den Haag	Utrecht
Agriculture and fisheries, mineral extraction	0.24%	0.14%	1.00%	0.12%
Industry	**8.95%**	**4.44%**	**3.43%**	**3.91%**
Utilities	**1.12%**	**0.08%**	**0.11%**	**0.06%**
Construction	**5.40%**	**3.00%**	**4.11%**	**4.09%**
Trade	12.00%	13.64%	10.93%	13.18%
Catering	2.99%	5.91%	3.41%	3.43%
Transport and communications	**12.29%**	**4.45%**	**7.86%**	**0.59%**
Financial institutions	5.62%	13.79%	4.01%	7.58%
Business services	**19.30%**	26.29%	17.33%	27.92%
Government, compulsory social security	5.94%	7.17%	20.45%	6.60%
Education	**8.17%**	**6.78%**	**5.54%**	**10.27%**
Welfare and health	**17.50%**	**13.56%**	**14.38%**	**16.68%**
Culture and OV services	0.46%	0.71%	6.58%	5.56%
Extra-territorial organizations and bodies	0.00%	0.04%	0.87%	0.00%
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**

Table 5.2 Share of employment by economic activities in major Dutch cities in 2008. Adopted from COS (2009)

5.2. Climate Change and Rotterdam

5.2.1. Rotterdam Contributes to Climate Change - Greenhouse Gases Emission

Whilst there has no data available specifically for the Rotterdam greenhouse gases emission, two nationwide figures are adopted in this section to provide a general impression among Dutch cities. The trend of Dutch CO_2 emission – which account for more than 95% of the total emission among all kinds of greenhouse gases (according to the data derived from CBS, 2011) – in the past two decades is illustrated with Figure 5.4. It shows a gradually growth in CO_2 emission in the Netherlands since 1990. Figure 5.5 shows the Dutch greenhouse gases emission in 2009 by sectors. It is evident that the energy, industry and transport sectors are the three largest greenhouse gases emitters which contributed more than 70% of the total Dutch emissions. In addition, the household sector also contributed around 11% of the total emissions. Referring to the study area, Rotterdam City accounts for approximately 16% of Dutch CO2 emission (Climate Office, 2010b). Furthermore, it has an emission value of 29.8 tonnes of carbon dioxide equivalent (tCO_2e) per capita; comparing to 12.67 tCO_2e for the Netherlands, it shows a significantly high amounts of emissions in Rotterdam (Hoornweg, Sugar, & Trejos Gomez, 2011).

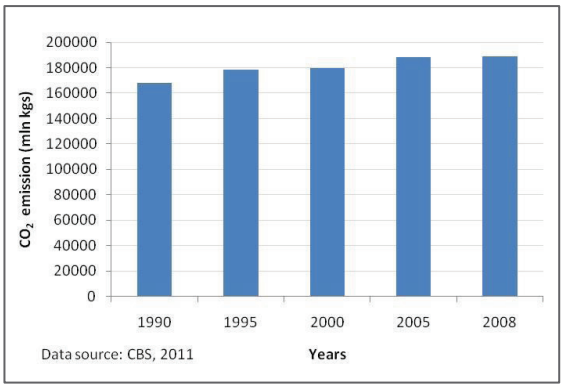

Figure 5.4 Trend of Dutch CO_2 emission from 1990 (data source: CBS, 2011)

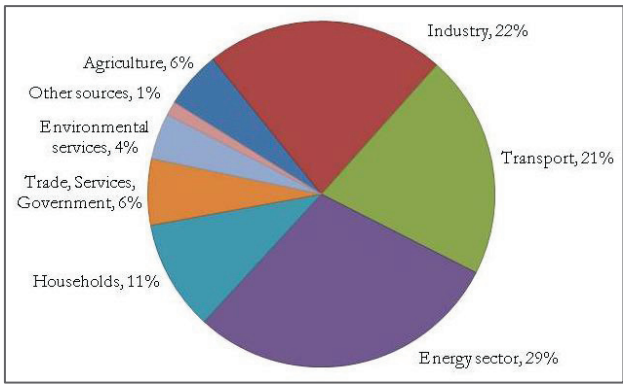

Figure 5.5 Dutch sectoral greenhouse gases emission in 2009 (data source: CBS, 2011)

5.2.2. Climate Change Affects Rotterdam - Climatic Impacts

Referring to national wide climate scenarios (KNMI'06 Scenarios), a decreased frequency but more intense rainfall in summer time is expected in the future (van den Hurk et al., 2006). Furthermore, increased precipitation in the upstream of the Nieuwe Maas River due to raised temperature will result in a higher river discharge (van den Hurk, et al., 2006). In addition, Rotterdam as a city closed to the coast is likely to be wetter in the summer than other inland cities under the influence of sea surface temperature (Lenderink, van Meijgaard, & Selten, 2009).Accompanied with projected sea level rising and the low-lying circumstance, Rotterdam City is now facing serious risk of flooding in the long run, not only from the seaside but upstream of Nieuwe Maas River (Climate Office, 2010a; van den Hurk, et al., 2006).

The increased likelihood of heat stress due to increased global temperature and urban heat island effect is the other major impact in Rotterdam under climate change (van den Hurk, et al., 2006). The daytime heat island in Rotterdam urban has been observed that can differs as large as 10 degree Celsius from non-urban area (Klok, Zwart, Verhagen, & Mauri, 2009). The heat stress will affect increasing numbers of people in health status and the living quality (Climate Office, 2010a).

5.2.3. Rotterdam Climate Initiative

In order to cope with forthcoming impacts and lower the greenhouse gases emissions, Rotterdam Climate Initiative (RCI) was established in Rotterdam in 2007 with a vision of year 2025 (RCI, 2007). It is a collaboration of four different parties, including the municipality of Rotterdam, Port of Rotterdam, Environmental Protection Agency (DCMR) and Deltalinqs (an organisation representing the business companies from city port and industrial area).

The entire initiative comprised of a mitigation objective (50% reduction of CO_2 emission compare to 1990) and an existing adaptation program (Rotterdam Climate Proof) which aims at a 100% climate-proof city. In general, the initiative includes numerous measures across energy, transportation, infrastructure, urban planning, building, and water management sectors.

It is noteworthy that the strategies to fight against the climate change in Rotterdam City are not only aimed at solving climate-related problems but at the same time exploring the potential for strengthening the economic state of the city and other environmental objectives such as air, water quality and noise pollution.

5.3. Analysis of Mitigation and Adaptation Measures in Rotterdam

Table 4.1 is a summary of mitigation and adaptation measures in Rotterdam. The measures are roughly categorised in five sectors, energy supply and infrastructure, water management and infrastructure, transport and infrastructure, physical planning, and building. In general, most of sectors are involved in mitigation programme in terms of directly and indirectly reducing energy consumption and CO2 emission. Conversely, adaptation largely involved in water management and infrastructure as a result of water-related threat to the City of Rotterdam.

5.3.1. Mitigation Measures

Since the energy supply sector is the largest greenhouse gases emitters in Dutch cities, major energy end-users in the urban area such as households, commercial-use buildings are then becoming the targets to promote mitigation measures in Rotterdam City to reduce energy demand. In addition, transport sector is another focus of mitigation projects as it emits gases directly into air.

5.3.1.1. Energy Supply and Infrastructure

Generally, in the energy sector, the mitigation programme seeks to develop alternative energy sources other than fossil energies, for instance, wind power, solar power and biomass power are desirable options. Furthermore, it pursues optimally utilising better efficient energy transfer through intelligent infrastructures such as smart grids. On the other hand, the heat/cold flow is been pursued to be optimally utilised as well. The facilities such as heat/cold storage and exchange system - which saves heat in the water body during summer for winter usage, and vice versa - would help to significantly reduce the energy consumption.

5.3.1.2. Water Management and Infrastructure

Purifying waste water is an energy-consuming process, however, rainfall water is not necessarily been purified. Therefore, separating rainfall sewerage from the sewerage for household and other types of waste water will reduce large amount of energy consumption. In addition, rainfall water itself can be reused for certain purposes such as heating/cooling system. Consequently the energy consumption for water transferring, for instance, pumping, can be conserved.

5.3.1.3. Transport and Infrastructure

In common with other cities around the world, Rotterdam City aims to drive a modal shift from motorised mode into non-motorised in the long run. For the medium or short run, promoting public transport such as bus, metro and water transport is the major task. On the other hand, use of energy-efficient vehicles, electricity power and bio-fuel are encouraged by the mitigation projects.

5.3.1.4. Urban Spatial Planning

Physical planning cam influence travel pattern in a city in a long run, therefore it is often designed to coordinate with transport sector in that sense. In addition, greenification of the city environment will help

in keeping low temperature in the urban area, thus energy consumption for cooling during hot summer will be reduce.

5.3.1.5. Building

Existing buildings in Rotterdam use twice or six times as much energy compare with new buildings (Climate Office, 2010b), thus it is important to keep advancing building technologies. Constructing an energy-efficient building involves in well building designing, use of sustainable materials, and introduction of green roofs, sometimes accompanied with special facilities such as underground heat storage. In addition, energy conservation plans are need for building-users to create good behaviour.

5.3.2. Adaptation Measures

The adaptation measures in Rotterdam largely involve in water management sector due to flooding-prone state of the city. In addition, planning and building sectors are entangled to solve increasing incidence of heat stress in hot summers. With respect to the ambition of Rotterdam to lead the technology and knowledge of water-related themes, few innovations such as floating building are remarkable.

5.3.2.1. Water Management and infrastructure

Tradition ways to control flooding risk in Rotterdam were to build dikes or barriers. Although dikes are still one of the main means in present days, they have been existed in new forms and new functions are going to be given; For instance, terrace levees which were built recently; This type of levee provides wider area on its top, thus neighbourhoods and transport connections can be developed on the inner side of the levee just like developing a small hill.

On the other hand, temporary water storages within the urban area are the other focus to adapt the climate change in terms of increasing likelihood of heavy downpour. With respect to their temporary usage characteristic, normally different functions are given during ordinary time, for instance, car parking or public open spaces (water plaza).

5.3.2.2. Physical Planning

The urban layout and designing influence the micro-climate within building environment which is associated to urban heat islands. Therefore physical planning is considered to be one of adaptation measures in Rotterdam to control adverse impacts in a new developed area. In addition, urban green features and water features are utilised to minimise urban heat island effect.

5.3.2.3. Building

As one kind of urban green features, construction of green roofs is therefore largely been deployed in Rotterdam City to adapt increasing temperature; furthermore, vegetation coverings can work as temporary water storage during heavy rainfall events.

One the other hand, different types of adaptive buildings are invested and developed in the city to adapt to gradually raised sea level and river discharge. For instance, elevated buildings have been applied to prevent propertied damage when river is overflowing; and the floating buildings are designed to be flexible and to provide a different life style (living on the water) in the near future.

5.3.3. Synergies and Conflicts between Mitigation and Adaptation Measures in Rotterdam

The measures summarised in Table 4.1 were further classified in terms of synergistic measures and conflicting measure based on the finding of investigation A. It is apparently that the cases of conflicts were not found in Rotterdam. This table will be used to compare to the information gathered from expert interview to discover whether the city planner recognises the synergies between mitigation and adaptation in Rotterdam.

Sectors	Mitigation measures	Adaptation measures
Energy supply & infrastructure	● **Promoting low-emission energy sources (e.g. wind, solar and biomass)** ● **Application smart grids & smart meters, and localised energy generation** ● **Investing in energy-efficient new developments** ● **Optimal using of the heat distribution network** ● **Utilise waste heat flows (e.g. heat and cold storage and exchange)** ● Research for geothermal heat source	
Water management & infrastructure	● Separated rainwater sewerage ● Rainwater collection and reuse	● Strengthening and heightening levees, quays and surge barriers ● Emergency water diversions ● Multifunctional (temporary) water storage space (e.g. water plaza and car parks) ● Multifunctional primary water defences (e.g. terrace levee) ● Increase storage capacity of existing sewerage system ● Regional water connection
Transport & infrastructure	● **Promoting energy-efficient infrastructure(e.g. LED Traffic light)** ● Promoting energy-efficient vehicles and renewable fuels (e.g. electric or bio fuel-driven vehicles) ● Promoting zero-carbon travel mode (e.g. walking and cycling) ● Providing alternative transport solutions (e.g. public transport)	
Urban spatial planning	● Intelligent spatial planning ● **Increase outdoor green spaces** ● **Promoting low-energy- consuming in public spaces (e.g. low-energy street light)**	● Better urban layout/design ● **Utilizing green areas and water as anti-heat-stress measures**
Building	● Invest sustainable buildings ■ **Low energy consumption** ■ Use of sustainable materials ■ **Use of residual heat, heat and cold storage** ■ **Green roof vegetation covering** ● Reduce CO_2 emission in every phase of a building's life cycle ● **Promoting energy conservation plan** ● **Retrofit historical and other existing buildings**	● **Promoting green roofs** ● Adaptive building ■ Amphibious building ■ Floating building/district ■ Elevated building ● Integrating buildings into dikes
* This table summarises the mitigation and adaptation measures which have been review by this investigation. The identification of synergies and conflicts are highlighted by colours where green shows the measures potentially create synergies and the red ones potentially cause conflicts.		

Table 4.1 Summary of mitigation and adaptation measures in Rotterdam

5.4. Summary of the Interview

5.4.1. Planner's View on Synergistic and Conflicting Measures

5.4.1.1. Measures that Create Win-Win Situation

Few measures have been recognised by local planner as examples of win-win situations while they can not only help the society in adapting to negative climatic impacts but also mitigate the drivers of climate change at the same time. There is an emphasis on that a better designed sewerage system could create win-win situations as Rotterdam as a flooding-prone city. If the ability to temporarily storage the rainfall water locally during heavily raining events is developed in the city sewerage and water management plan, the energy consumption to solve the flooding such as water pumping could be saved. On the other hand, separating rainfall sewerage system form the sewerage for waste water is also advantaged whilst rainfall water is not necessary to be purified, but for which a temporary drainage is needed.

Another example is the insulation of buildings. Through designing of the building and the use of special materials, the indoor temperature gradient is persevered to stay steady in a certain time. Therefore it keeps indoor air warm in the cold winter and cool in the hot summer without consuming too much energy on the heating system and air-conditioner – which are largely used to resist severe weathers such as heat summers and cold winters.

The last example is the construction of green futures in the urban area, such as green roofs and green façades. These kinds of green futures can effectively reduce the degree of the urban heat island effect, and work as temporary water storage during raining events (Climate Office, 2010a). At the same time, a cooled urban area would reduce the energy consumption for building cooling systems. Therefore a win-win situation in terms of mitigation and adaptation can be created.

5.4.1.2. Measures that Potentially Create Conflicts

It is generally agreed by local planner that densification of the building environment for mitigation purpose in Rotterdam will cause a more serious urban heat island effect. However, it is attempted to be solved by introducing more green features in the urban area such as green landscapes, green roofs and green façades while densification is the tendency for future urban development (Climate Office, 2010a). The other example of conflicting is the building cooling systems such as air-conditioner, which works to adapt to increased heat stress, is actually transferring the heat from indoor to outdoor. It results in may be minor but more intense heat stress, further increases the total usage of air-conditioner and energy cost.

It is likely that whilst local planners in Rotterdam are paying much more attention on the measures which create win-win situation in terms of mitigation of and adaptation to climate change, the situations where mitigation measures conflict with adaptation purpose, and vice versa, are less been noticed. It could be reasoned from two points. The first, although the contradictions might exist, alternatives can be developed to avoid the problem, for instance, introducing a combination of decentralized and centralized energy generation system could reduce the vulnerability of relying on too narrow climate-sensitive energy supplies (Swart & Raes, 2007). Thus the conflicts are not necessarily happening. Secondly, rather than paying attention on the contradictions between two types of measures, the more significant challenges for Rotterdam City is to efficiently implement mitigation and adaptation measures and to coordinate different departments (see section 5.4.2).

5.4.2. Challenges for Integrated Climate Strategy

5.4.2.1. Institutional Structure and Coordination

The main challenge for Rotterdam City to successfully develop an integrated mitigation-adaptation climate strategy is to integrate institutional structure. Although a combined climate initiative (RCI) has been

developed and a combined bureau has been established, there is still a clear division between mitigation and adaptation working groups. However, the issue could be reduced in the future by involving members from both aspects in frequent communications or committees.

Besides to internal institutional integration, promoting well coordination between different institutions is also a considerable challenge; especially in a situation when planning to combine mitigation and adaptation measures in a single development, for instance, combining wind turbine with sea dikes. Normally there will be two institutions or organisations as one for mitigation measure and the other one for adaptation. Sometimes it will end with competition where the adaptation department might argue that safety should get higher priority than sustainable energy.

5.4.2.2. Mainstreaming into Planning Process

The other challenge associated with implementation of mitigation and adaptation measures in Rotterdam City is to mainstreaming it into normal planning procedure. Once the possibility of climate measures is explored in the beginning of new developments, the goal will be easier to be achieved than considering them as additional functions in the later stages of planning process. Therefore win-win situations would be easier to be created, and the contradictions would be avoided.

However, Rotterdam is still in a rather difficult position while the plans and projects are usually tight scheduled and limited in finance; Project managers may not willing to spare human resource or monetary cost on the investigation or even think it is not necessary. It is believed that the issue could be solved if there are clear statements revealing the ambition to mainstream the ideas of climate change mitigation, adaptation and environmental sustainability into the normal planning process.

5.4.2.3. Competition in Finance

The last challenge indicates the financial competition between mitigation projects and adaptation projects. Although finance and resources for development are always limited, it is considered as one of the reasons for Rotterdam City to seek for mitigation-adaptation integration. When a single measure can achieve the goals of mitigation and adaptation at the same, it is more beneficial than do it twice for each aspect.

5.5. Discussion and Conclusion

The summary of mitigation and adaptation measures has been presented in this chapter; and the synergies were identified. The result reveals that whilst the city planner recognised a few examples of synergistic measures in the city which can be categorised into the conditions concluded in investigation A, a new type of synergistic measures can be identified in this investigation – which is associated with water management, the separation of rainwater sewerage from wastewater sewerage(section 5.4.1.1). However, the summary of the interview also discovered that whilst the city planner recognised synergies, the more important issue from the practical perspective is related to the institutional structure, finance limitation and the implementation of the measures.

6. PERCEPTION OF MITIGATION AND ADAPTATION: FUZZY COGNITIVE MAPPING

6.1. Overview of the Result

Totally 18 valid mitigation maps and 19 valid adaptation maps were collected through a group exercise session with 22 participants (see section 3.4.1). The reason for invalidation was incompletion of connections (mainly because the weightings were missing). Overall, 12 countries (5 African, 4 Asian, 1 South American and 1 European) and 10 cities were specified where the participants' fuzzy cognitive maps were referring to (Table 6.1). It is worthy to note that more than 50% of participants with valid maps were referring to African countries or cities (11 in total); therefore the result of this investigation may differs from the general situation in the rest of the world.

Participant number	Specified country	Specified city
1	Egypt	Cairo
2	Egypt	Cairo
3	Egypt	Cairo
4	Egypt	Cairo
5	Ethiopia	Mek'ele
6	Ethiopia	
7	Ethiopia	
8	China	Beijing
9	China	
10	Kenya	Nairobi
11	Kenya	
12	Bolivia	Santa Cruz
13	Nepal	Kathmandu
14	Tanzania	Zanzibar
15	Bangladesh	Dhaka
16	India	Agra
17	Philippines	Quezon
***18**	***Rwanda***	
19	Netherlands	

The mitigation map from Participant 18 was not valid.

Table 6.1 List of countries and cities where the participants were referring to for the maps

6.2. Preliminary Maps

The preliminary outputs of fuzzy cognitive mapping are presented in Appendix II and III where the concepts are visualised by nodes and connections are visualised by arcs. The size of the concepts represents the frequency a certain concept was mentioned by the participants; the width of the connections represents the strength of certain cause-effect relationship as well as the frequency a certain connection was mentioned by the participants; and the colour of the connections shows the correlation of the relationship where the black lines indicate positive relationships, and the red ones the negative relationships. The analysis on the structure of both preliminary maps and the main concerns among the participants are presented in the following sections.

6.2.1. Structure of Preliminary Maps

Indices	Preliminary Mitigation Map	Preliminary Adaptation Map
Map density	0.0419	0.0177
Number of connections	141	177
Number of concepts	58	100
Number of transmitters (percentage)	14 (24.1%)	27 (27%)
Number of receivers (percentage)	13 (22.4%)	19 (19%)

Table 6.2 Structural indices of the preliminary maps

Table 6.2 provides the fuzzy cognitive map indices indicating the structure of the preliminary maps. The mitigation map has a higher map density and less number of concepts which means the participants perceived more shared concepts and more inter-links between concepts compare to the adaptation map. In contrast, the adaptation map consists of large amount of concepts but lower map density, which indicates that the participants had rather different perception on the topics of climate impacts. Their own different origins, experiences, and interests might be the main reason of the diverse perception. The observations are also evidenced in Appendix III where the adaptation map shows several separated clusters of concepts compare to mitigation map (Appendix II) which is relatively more compact. On the other hand, the participants were likely to perceive the "mitigation system" as a rather open system with many influences and consequences whilst the total amount of transmitters and receivers comprise almost half of total amount of concepts in the mitigation map. Conversely, although the "adaptation system" was also likely to be perceived as an open system with

high amount of transmitters and receivers, the diverse influences are likely leading to rather similar consequence as the receivers are less than transmitters.

6.2.2. Categorisation of Concepts

The present concepts were further been categorised into 12 categories according to the meaning of the concepts. The main purpose is to reveal the participants' main concerns relate to greenhouse gases emission and the climate impacts. The categories are: (1) Climate-related attributes, phenomena and impacts, (2) Agricultural activities and issues, (3) Industrial activities and issues, (4) Transport/mobility attributes and issues, (5) Energy demand and supply issues, (6) Health issues, (7) Water resource security and issues, (8) Environmental state and issues, (9) Built environment state and activities, (10) Social-economic state and issues, (11) Other human activities, and (12) Measures and responses. Table 6.2 summarises the frequency distribution of the concepts in both preliminary maps. It shows that the concepts in the mitigation map are likely to concentrate on climate-related attributes and phenomena such as "greenhouse gases emission" and "increased average surface temperature". In contract, the concepts in the adaptation map are rather focusing on the shifts in the built environment such as "uncomfortable life environment" and "change types of building construction", and the impacts on the social-economic aspect such as "loss of property".

Category	Preliminary Mitigation Map	Preliminary Adaptation Map
(1) Climate-related attributes, phenomena and impacts	**16**	**12**
(2) Agricultural activities and issues	3	5
(3) Industrial activities and issues	2	1
(4) Transport/mobility attributes and issues	6	4
(5) Energy demand and supply issues	1	3
(6) Health issues	3	2
(7) Water resource security and issues	2	9
(8) Environmental state and issues	5	8
(9) Built environment state and activities	5	**15**
(10) Social-economic state and issues	8	**26**
(11) Other human activities	2	3
(12) Measures and responses	5	**12**

Table 6.3 Frequency distribution of concepts in the preliminary maps by category

6.3. Concise Maps

Whilst the preliminary mitigation and adaptation are far too complex to understand, a simplification process was employed to generate the concise maps (see Section 3.4.3). Further visual interpretation and indices interpretation are presented in following sections.

6.3.1. Map of Mitigation

6.3.1.1. Visual Interpretation

The concise mitigation map (Figure 6.1) retains the characteristic of the preliminary mitigation map after the process of simplification: compact and the concepts are highly inter-linked. However, it is surprising that "air pollution" is likely to be perceived as a more important concept than "greenhouse gases emission" by the participants whilst the topic question was actually asking for the perception of greenhouse gases emission. The reason might be that some of the participants did not have a clear understanding on what is greenhouse gases emission, therefore leaded them mistaking it as air pollution.

From Figure 6.1 one can see the two concepts ("greenhouse gases emission" and "air pollution") are situated in the centre with "industry" contributing a strong effect on both; and both of them lead to "increased average surface temperature" , "health problem (respiratory disease)", eventually "energy

consumption", "overcrowd hospital" and "household income". The other influences are transport-related as "traffic", "number of vehicles" and "congestion". Notably, few concepts related to social-economic state ("employment" and "economic situation"; on the left of Figure 6.1) stand out from simplification process, which means that the participants perceived the topic (greenhouse gases emission) is indirectly linked to social-economic issues in some way.

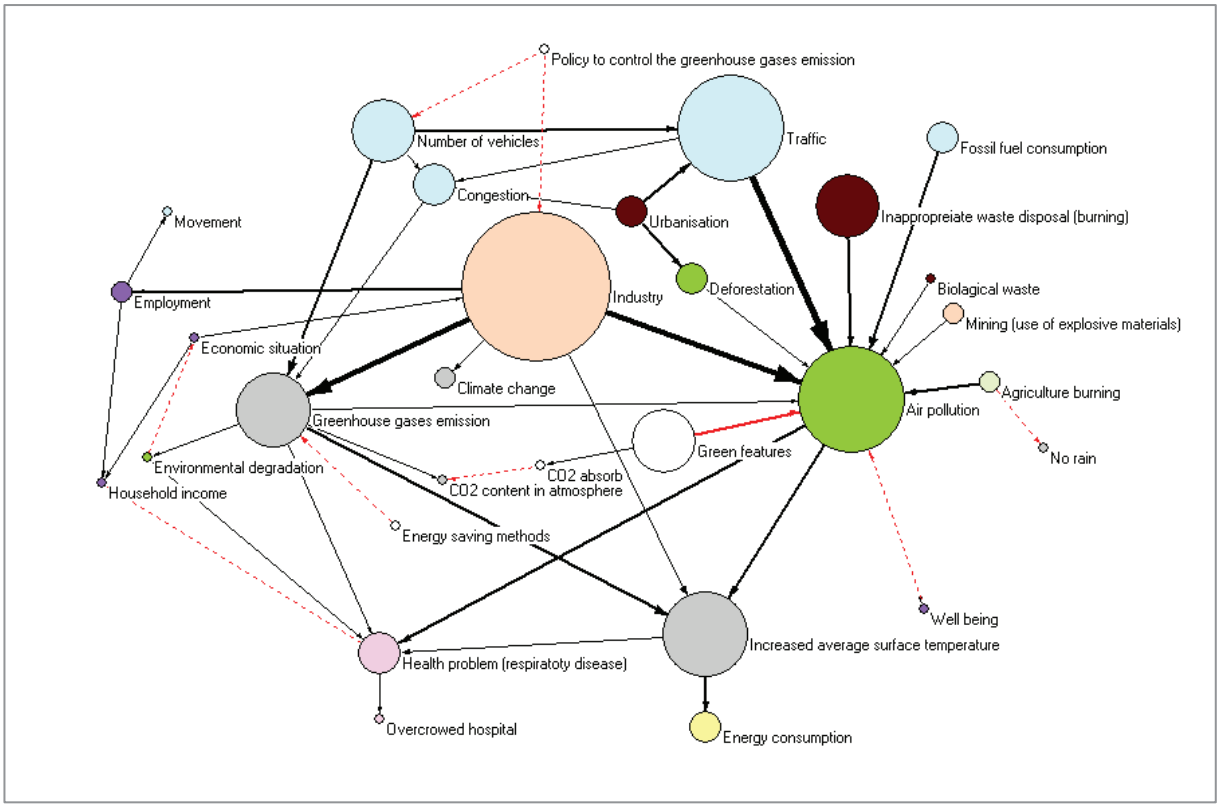

Figure 6.1 Concise mitigation map

6.3.1.2. Indices Interpretation

Table 6.4 ranks the top 25% of concepts which have the highest outdegree and indegree. The two indices respectively reveal the most influential concepts and the most effected concepts in the system (see section 2.4.2). In this case, the concepts have higher outdegree means that these concepts might be the important entry points of intervention in terms of mitigation measures whilst they are the "common views" among the participants; in the other words, more acceptances for the interventions.

Concepts ranked by…	
Outdegree	**Indegree**
Industry	Air pollution
Greenhouse gases emission	Greenhouse gases emission
Traffic	Increased average surface temperature
Number of vehicles	Health problem (respiratory disease)
Air pollution	Traffic
Urbanisation	Industry
Increased average surface temperature	Congestion
Green features	Household income

Table 6.4 Concepts ranking by highest outdegree or indegree (for the concise mitigation map)

With respect to the concepts with highest indegree, some of them represent the consequences of greenhouse gases emission and/or air pollution (increased average temperature and health problems); and some are emitter themselves but also influenced by other factors (traffic). However, the rest are likely being effected strongly by interventions, depending on the position of certain concepts in the network, either in a positive way ("industry" decrease as "policy to control the greenhouse gases emission" increase), or in a negative way ("household income" reduced whilst "industry" reduced) (see Figure 6.1).

6.3.1.3. Possible Mitigation Measures

Summarising above sections, measures to control the greenhouse gases emissions from industry and the transport sectors, and the provision of green features will be feasible mitigation options, and are like to work efficiently according to the participants' perception. Another possible measure is methods to save energy consumption which is directly been mentioned as a concept in the map. In addition, controlling the process of urbanisation would also achieve the goal in an indirectly way though it might be difficult to implement. However, interventions to reduce emission from industry sector might result in the reduction of household income, yet the actual level of the reduction is unable to be answered by this investigation.

6.3.2. Map of Adaptation

6.3.2.1. Visual Interpretation

The concise adaptation is visualised in Figure 6.2. It is interesting that there are quite a few number of "concept islands" emerged after the process of simplification. It reveals that to a certain extent the participants perceived week linkages – which have been erased in this map – between the climate impacts and the other systems (the "islands"). Yet, the number of the "islands" again indicates the diverse background and experiences of the participants.

Apparently, in the main structure in the adaptation map, the participants perceived that the climate change impacts are directly inter-linked. Whilst the first effected concepts are diverse, most of the impacts eventually result in four main issues: "property loss", "traffic congestion", "loss of agriculture", and "health problems/diseases". On the other hand, there are quite a little amount of concepts related to social-economic state and issues are perceive to be influenced by the impacts such as the performance of works, the food prices, and the economy loss. It indicates that the climate change is perceived more as a social-economic issue than other aspects.

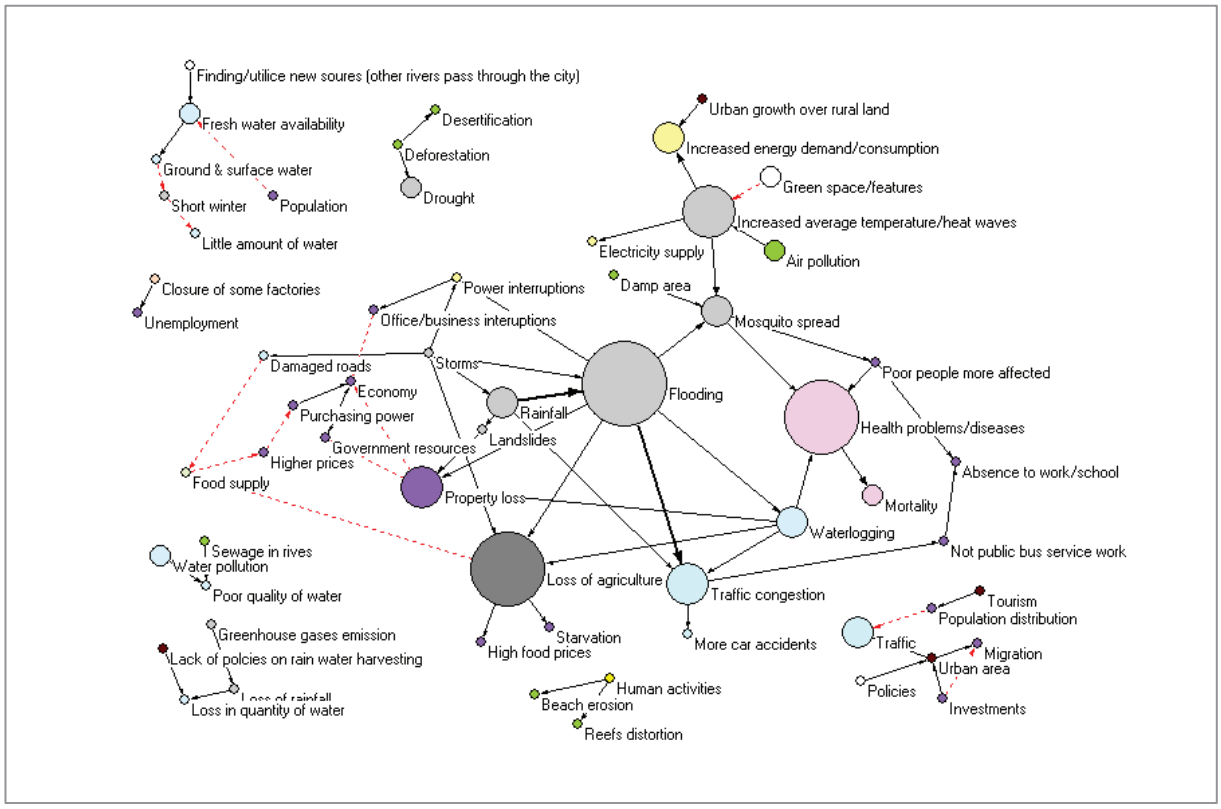

Figure 6.2 Concise adaptation map

6.3.3. Indices Interpretation

The top 25% concepts which are ranked the highest in outdegree and indegree are listed in Table 6.5. Differing from the mitigation map, the concepts which have highest outdegree in the concise adaptation map are the climate changes impacts themselves. It also reveals that which impacts are more perceived (more felt) by the participants than the other impacts. In this case, the issues of flooding, storms and rainfall are the most ones (Table 6.5). In other words, the consequences of these impacts are the most urgent to be tackled by the means of adaptation measures. With respect to those have higher outdegree but located at the "concept islands", it is rather difficult to judge their value whilst they might be important for the participants but however not obvious in the concise map.

Concepts ranked by…	
Outdegree	**Indegree**
Flooding	Traffic congestion
Storms	Mosquito spread
Rainfall	Economy
Water logging	Flooding
Increased average temperature/heat waves	Loss of agriculture
Loss of agriculture	Property loss
Mosquito spread	Health problems/diseases
Traffic congestion	Increased energy demand/consumption
Property loss	*Urban area*
Urban area	*Fresh water availability*
Investments	Government resources
Deforestation	Power interruptions
Poor people more affected	Food supply
Human activities	*Traffic*

Italic text indicates the concepts which are located in the "islands"

Table 6.5 Concepts ranking by highest outdegree or indegree (for the concise adaptation map)

Except for the impacts caused by other impacts ("mosquito spread" and "flooding") and the ones located at the "islands", the other concepts which have highest indegree indicate the most important issues perceived by the participants under the climate change impacts. The most concerned issues are: "traffic congestion", "economy", "loss of agriculture", "property loss", "health problem/diseases", and "increased energy demand/consumption". These sectors are therefore the priority for developing adaptation measures.

6.3.4. Possible Adaptation Measures

Synthesising above sections, developing adaptation measures to improve the transport, agriculture and health service sectors are the priority according to the condensed map. In addition, improvement in the social-economic state is another pathway. One feasible concrete adaptation option is the promotion of urban green features; it is perceived to have an effect for reducing the impact of increased average temperature. Few other concrete actions can be develop based on the concepts in the map, for instance, improve road infrastructure to respond "damaged roads", improve energy supply capacity to respond "increased energy demand/consumption". However, in most conditions, the concrete adaptation measures are not directly emerged from the result thought the most urgent issues can be identified.

6.4. Linkages between Mitigation and Adaptation Maps

Few similar concepts in both concise mitigation and adaptation maps can be found. One is that the impact of increased air temperature is mentioned in both mitigation and adaptation maps. On one hand, it indicates, obviously, the participants perceived the connection between greenhouse gases emission and the increasing in air temperature. On the other hand, it also indicates that, to a certain extent, the participants do not associate other types of impacts (e.g. flooding) with the greenhouse gases emission. The second type of similar concepts in both concise mitigation and adaptation naps is that the participants perceived both greenhouse gases emission and climate change impacts will lead to the consequence of health problems. Whilst the emission introduces respiratory diseases, the climate change impacts result in diseases associated with water logging and the spread of mosquitoes. The third type of linkages shows that the climate change impacts may results in more emission of greenhouse gases. Whilst the participants perceived the impacts of flooding and rainfall will result in the consequence of traffic congestion, the

concept ”traffic congestion” is also perceived by the participants that it will introduce greenhouse gases emission at the same time.

In terms of synergies and conflicts between mitigation and adaptation measures, it is however less obvious based on the results of this investigation. The only synergy that can be identified from concise mitigation and adaptation maps is the promotion of urban green features. It is perceived by the participants as it can not only reduce the level of greenhouse gases in the atmosphere (from the mitigation map), but also reduces the impact of increased average temperature or heat waves (from adaptation map).

6.5. Discussion and Conclusion

The collection of perception maps has been analysed and the results have been presented in this chapter. The interpretation of the concise maps has revealed few possible interventions in terms of mitigation and adaptation measures. However, whilst few linkages and similar concepts can be found between two maps, the synergies and conflicts between mitigation and adaptation are rather less obvious in the results of this investigation. The main reason of the failure may be the inappropriate set-up of the methodology; it will be discussed in chapter 7. The only synergy can be identified from investigation C is the promotion of urban green features. It was perceived as a measure which can reduces the greenhouse gases level as well as the impact of increased air temperature.

7. DISCUSSION AND RECOMMENDATION

7.1. Discussion on the Findings

7.1.1. Overall Findings

Table 7.1 summarises the situations (conditions) when the synergies can be achieve and conflicts may be introduced; and in which investigation these conditions were identified. Overall, four conditions for a measure to potentially create synergies and two conditions for a measure to potentially cause conflicts were identified in this research. Whilst condition [4] was identified from investigation B (section 5.x) and the rest were identified from investigation A (section 4.3), investigation C did not contribute new findings to the objective of this research. Each condition are briefly introduced as follow; for more details, readers can refer to chapter 4, 5 and 6 where described how this conditions were identified.

		Investigation		
Synergistic Condition	**Example measures**	**A**	***B****	**C**
[1] Reducing energy demand and/or consumption	Price policies to discourage energy consumption; increase in the energy efficiency of appliances	●	○	
[2] Developing renewable energy sources	Utilise of wind energy; development of solar energy	●	○	
[3] Promoting urban greening	Designing green roofs and green facades; planning green open spaces	●	●	●
[4] Separating rainwater collection and sewerage system	Separating rainwater drainage from wastewater sewerage		●	
		Investigation		
Conflicting Conditions	**Example measures**	**A**	***B****	**C**
[5] Increasing the consumption of high emission source	Shifting from hydropower to coal-fired power generation	●		
[6] Densification of built environment	Compact city planning; high building density city plan	●	◎	

* In the findings of investigation B, ● means the synergistic/conflicting measures were implemented and were recognised by city planner; ○ means the synergistic/conflicting measures were implemented and were not recognised by city planner; ◎ means the reorganisation was influenced during the interview.

Table 7.1 Summary of the findings in three investigations

- **Synergistic Conditions**

[1] Reducing energy demand and/or consumption - From adaptation point of view, the researchers considering the reduction of energy consumption is a way to reduce the possibility of energy overload due to increased cooling demand; at the same time, energy generation is a major greenhouse gases emission source, therefore reduced the energy consumption will also achieve mitigation.

[2] Developing renewable energy sources – Whilst mitigation aims at developing low-emission or zero-emission energy sources, adaptation sees it as a chance to develop multiple energy sources to reduce over dependence on small number of energy sources.

[3] Promoting urban greening – Urban greening on one hand helps in reducing the temperature in the built environment, on the other hand functions as temporary water storage during rainfall event – reduce

the likelihood of flooding. At the same time, the energy consumption for cooling will decrease as temperature decrease; In addition, vegetations can directly reduce the CO_2 level in the atmosphere.

[4] Separating rainwater collection and sewerage system – Separating the sewerage for rainfall water from the wastewater sewerage system can build a higher capacity in terms of temporary rainwater storage. On the other hand, it can avoid unnecessary energy consumption for wastewater purification whilst rainwater is necessary to be purified.

- **Conflicting Conditions**

[5] Increasing the consumption of high emission source – In some cases, adaptation measures are likely to introduce more consumption in high emission energies, for instance, reduce the share of climate-sensitive energy sources may result in expansion on the coal-fired power generation. However, this condition is rather hypothetical whilst the way the measures are implemented will ultimately determine whether they will introduce conflicts or not.

[6] Densification of built environment – From mitigation point of view, city plans tend to create a rather compact built environment to reduce the usage of private vehicles. However, most adaptation measures purpose green open spaces which require lower density of built environment. Therefore the conflict was identified.

From Table 7.1, one can see that in most of the situations, the cases of synergies or conflicts happened in the energy or urban spatial planning sectors and, unsurprisingly, associated with the consumption of energy. From the other point of view, it indicates that whenever a new adaptation measure incorporates the idea of reduce energy consumption – either directly or indirectly, the synergies can possibly be created, or at least, the conflicts can be avoided or reduced. In the some way, it can be inferred that if mitigation measures incorporate the idea of reduce vulnerability to climate change impacts, the synergies can be create. However, the latter situation is less obvious based on the findings unless the reduction of energy consumption is considered as a way to reduce vulnerability in the energy sector (condition [1]). Yet, it result in, to a certain extent, a rather vague distinction between mitigation and adaptation in the energy sector whilst the objective of mitigation becomes a way to achieve adaptation.

7.1.2. Cross-Perspective Comparison

7.1.2.1. Academic Perspective versus Practical Experience

The view point from practical perspective (investigation B) can be used to confirm whether the synergistic measures identified from academic perspective (investigation A) are practicable and real. Based on the findings of this research, one conditions of synergies – [3] promoting urban greening – was confirmed by city planner in Rotterdam and example measures are provided during the interview. With respect to the measures which can potentially cause conflicts, urban densification (condition [6]) was agree by city planner in Rotterdam, however, this particular finding might be influenced by the interview question – which directly mentioned that this measure has been considered as a conflicting case (Appendix I; Question 12). Therefore it can be judged that the synergy created from urban greening measures is indeed workable and real. On the other hand, the conflict induced by urban densification process is true, and needed to be dealt with.

There are two conditions – [1] reducing energy demand and/or consumption and [2] developing renewable energy sources – were implemented in Rotterdam according to the documents but not recognised as the cases of synergy by the city planner. However, it does not mean these two types of measures are impracticable; they are just unproved, and perhaps, limited by the amount of interview conducted in this research. Similarly, the new type of synergistic measures which was identified from

expert interview – condition [4] separating rainwater collection and sewerage system – does not means that the synergy is imagined by the planner; but possibly limited by the amount of literatures reviewed in this research.

7.1.2.2. Practical Experience versus Citizens' Perception

Whilst the investigation C highlighted the important entry points of mitigation and adaptation measures, the synergistic measures identified through perception maps in investigation C indicate the certain measures may have a higher social acceptability. Therefore the result can be used to cross check whether the implementation (investigation B) meets the "expectation" from the citizen's point of view. Based on the results of this research, an overlapping between investigation B and C indeed exist – condition [3] promoting urban greening. This finding therefore signifies the important role of urban greening measures in terms of developing synergies between mitigation and adaptation. However, the mismatch on the spatial scale between investigation B and C – whilst the former one focused on the case of Rotterdam, the latter one captured the perception of participants from several countries – may reduce the reliability of this judgement as the participants of investigation C are not really the inhabitants of Rotterdam.

7.1.2.3. Citizen's Perception versus Academic Perspective

Whilst the investigation C highlights the citizens' expectation of mitigation and adaptation measures, the result can therefore be used to examine that whether the academic opinions are relevant to the citizens. According to the result of this research, condition [3] promoting urban greening shows an overlapping between two perspectives. It is again signifying the importance of urban greening measures as a role to create synergies between mitigation and adaptation. However, the result is limited by the number of participants in investigation C; it is possible that when more samples were included, more relevancies between two perspectives could be found.

7.2. Discussion on Research Method

A multi-method research approach has been applied in this research. In spite of that the findings of investigation B and C contributed rather limited ancillary results to strengthen the finding of investigation A in terms of identifying synergies and conflicts between mitigation and adaptation measures, two additional findings which are however difficult to be discovered by the method applied in investigation A were found – the practical issues in terms of implement and facilitate integrated mitigation-adaptation strategy were found in investigation B, and the practicality of fuzzy cognitive mapping for identifying important mitigation and adaptation entry points was found in investigation C. These two additional findings are then highlighting the advantage of multi-method approach.

With respect to the shortcoming of the approach applied in this research, the most notable issue is the mismatch in the spatial scale of the three investigations. Whilst the investigation A tried to include several literatures which are contributed by scientists from worldwide; the investigation B focused on rather single case study – Rotterdam City; and the investigation C lacks for the samples from earlier developed countries. This issue might result in a difficulty for comparing the findings from different investigations.

The following subsections discuss the limitation and the shortcomings of each investigation and the possible factors that may influence the overall finding of this research.

7.2.1. Investigation A

The method adopted from Hamin and Gurran (2009) provides a rather structured way to analyse and identify the synergies and conflicts between mitigation and adaptation measures. However, this is certainly limited by the time available and the amount of literatures accessible. Yet, in some cases, the determinant of synergies and conflicts is likely to be subjective and hypothetical – which raise the need for other

empirical evidences to prove the theoretical point of view. The multi-method approach similar to the one applied in this research may provide a solution to include empirical investigation to cope with the shortcoming.

7.2.2. Investigation B

The investigation B was certainly limited by the number of expert interview which has been conducted. Although one expert who is working on a key position may provide useful information, however, the information may be rather bias and cannot represent the majority. Furthermore, in terms of practical experience, additional case studies may be needed to generate comparable and robust findings. Yet, the number of cities which have both mitigation and adaptation plans is rather less. Alternatives could be to include other types of city wide plans such as master plans to identify explicit mitigation or adaptation measures.

7.2.3. Investigation C

7.2.3.1. Choice of Knowledge Source

In the set-up of this research, the investigation C aims to extract the tacit knowledge from the citizens who are the users of mitigation and adaptation measures. Knowledge from citizens may be useful to acquire the demand and important entry points of mitigation or adaptation measures; however, it is rather unsuitable in terms of identifying synergies and conflict. The main reason is that the citizens are not necessary to know how exactly the measures work, and what are the outcomes of the measures expect those the citizens are demanding. Yet, this knowledge is vital for finding out whether a mitigation measure can lead to consequences (either positive or negative) on adaption, and vice versa. Therefore the professionals who are working on those measures may be the better choice of knowledge sources for this research topic.

7.2.3.2. Understanding of the Questions by Participants

The understanding of the topic question by the participants is likely to effect the result, especially when the topic is relatively new to the participants. It is reflected on the finding of investigation C, where a number of participants misunderstood "greenhouse gas emission" as "air pollution" and therefore lead to an unexpected result. The misunderstanding may be result from inadequate introduction on the question and the topic. The issue can be solved by providing enough information about the topic; however, this action might also influence the result whilst too much information was provided – the participants might draw the map depend on the introduction instead referring to their own experience.

7.2.3.3. Method for Combining and Simplifying the Result

The last factor that may influence the result in this research is the method applied to combine and to simplify the perception maps – which two steps involved relatively subjective decisions. Whilst combing the individual perception maps, the coding of concepts was judged by the author. Thus misinterpretation of the original meaning of certain concepts might cause errors on the coding. On the other hand, the choice of the way to generate the weighting of the connections in the combined map directly influenced the output whilst the opinions from individual participant were reduced. In the same way, the choice of the way to simplify the preliminary map also influence the identification of linkages between mitigation and adaptation maps whilst a concept might be kept if other type of simplification was applied.

7.3. Rcommendation

A number of synergies and conflicts between mitigation and adaptation measures have been identified in this research; and the methodological shortcomings have been discussed in the last sections. In this section, this research attempts to propose mainly one commendation reflecting on the topic of developing integrated mitigation-adaptation strategy.

7.3.1. Mainstreaming Mitigation and Adaptation

Whilst identifying the synergies and conflicts indeed helps in developing linked mitigation and adaptation strategy, however, this research revealed that only the implementation will determine whether the synergies or conflicts happen in reality (section 4.4). Moreover, the investigation B in this research revealed that, from the practical perspective, the challenge is not to find out the synergies but to let mitigation or adaptation measures successfully implemented whilst the finance is usually limited (section 5.4.2). Swart and Raes (2007) also suggested to mainstreaming the considerations of mitigation and adaptation into the general development policies. Therefore rather than widen the view for searching synergies or conflicts, it may be more feasible to focus on the question of how to successfully incorporate the ideas of mitigation and adaptation into each individual development.

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APPENDIX

Appendix I. Transcription of Exper Interview

Note

Interviewee: Mr. Wim de Jager

The interview was carried out on 9 Dec. 2010 at 8:30 in World Trading Center Rotterdam. The total time was approximately 50 minutes. The whole interview was recorded with permission. It is transcribed in below.

Content

Q1: May I ask first your role in this programme?

A1: Yes, I am a member of the steering group of the Rotterdam Climate Proof programme. There is a project organisation, Rotterdam Climate Proof. But that organisation is not working at the problem on itself alone. It is also using people from the other part of the city of Rotterdam. I am myself part of the municipality, the Civil Engineering part. We are part of the engineering bureau, and also participating in the Rotterdam Climate Proof programme. I am myself a team manager of a team with 22-25 people. A number of people are also working in this programme, for instance, the project leader of the heat stress, and the heat island effect is one of my team members. We are also working on the Rotterdam adaptation strategy, it is also climate proofing. In my team there are also people who are working for the Rotterdam Climate Initiative, which is more on the mitigation side of the programme.

We are investigating in urban development how can we make it less energy consuming, and looking for the opportunities for sustainable energy; and the reusing of waste heat from the industry. Members from my team are working for both programmes as well mitigation as adaptation.

Q2: So actually your team work for mitigation and adaptation. We know in the past people are used to consider they are separate thing. How do you think on this, are there any relationship between mitigation and adaptation?

A2: Yes, many relationships. For instance, the heat stress which may occur more in the future. The urban heat island effect means that in the dense urban area temperature is going up more than in the rural. If you don't take measures from the adaptation point of view, you can just predict that the demand for cooling will grow in the future. Most people would take an air-condition unit or something like that, which increases the emission of CO2 a lot. So there you see one of the things where adaptation and mitigation are closely related. If we can adapt to the urban heat stress, for instance, take measures like adding green and water in the dense urban area, then the overall temperature will decrease, and then the demand for cooling will also decrease, relate to what we do normally. So there is a close relation between adaptation and mitigation.

Another example is, for instance, getting rid of waste water from the streets. The sewerage system can be differentiated; one part is for the rain water, and one part is for the real dirty water from households and companies. If you split it up, and you have a differentiate system, then the part which is really needed to purified, the dirty part is much smaller. From the adaptation point of view, it is more advantage because we expect more heavy rain fall in Short time. So a separate sewerage for the rain water is profitable. Because then you don't have to take as much, you can easily let go on the surface water. So for adaptation it is advantage, but also for mitigation because you have a smaller, less capacity in your purifying plan. It also cost you less energy because cleaning the water cost a lot of energy. That is another example.

Then we have a third one which is also connected to the sewerage system. From adaptation and water management point of view, it is most beneficial to keep the water away, fall off the rain water. So just hold

it in the neighbourhood, make it have time to go into the subsoil again. If you can manage that then you should try to collect it in local places, a water collection. If you can't manage that, then you should pump it away. But if you manage to do this sufficiently then a lot of water you don't have to pump it away any more, because it is collected locally where it is fallen. So you don't have to pump as much water as well. So also your pump energy can be saved. So there is also connection between adaptation and mitigation

Q3: Sorry, for clarify, you mean collect the rainfall water for use or…?
A3: Well, it can be just a storage which is locally divided, so which can be full when we have a lot of rain, and it can evaporate again. It is some kind of buffer which helps us to collect the water and not let it go on the street. Therefore we don't have to pump away all the water straight away, just leaves it there for the time being.

Another example is the isolation of houses. If we have a good Heat isolation, it helps against heat waves in the summer because if you have a well isolated house, it helps to keep the heat out. But it also helps in the winter to keep the heat in and you don't have to use your heater so much. It is also one thing there is win-win situation.

Another example is the green roof. It is applied a lot In Rotterdam. Green roof is having a number of advantages. An advantage is for collecting rain water. Especially when you have rainfall, it can delay the water given to the Sewerage system. It can also help reduce the heat island effect. It can help isolate the roof. So there are a number of effects where it is beneficial for as well adaptation and mitigation purposes.

These are a number of examples where we see win-win for the both things. Of course there is also to a certain extends, they both Put the demand on the means of finance and the capacity of people. So two years ago, Rotterdam decided to integrate adaptation and mitigation together. Therefore there is also the Balancing of the two aspects in one programme office for mitigation and adaptation at the same. Also the priority will be advised to the colleague of the municipality.

Q4: So the reason you tried to combine mitigation and adaptation groups is because if they are separate, they will cost more money or more human resource?
A4: I am not sure if it will cost more human resource but I am convinced that it can help, there are numbers of measures like I indicated which help both things so we can have a win-win and then so we don't have to do separately. In that way it might save time and money. So that is correct.

I also think that one of the main challenges for the coming time for Rotterdam is to let the ideas of mitigation and adaptation have them taken up in Mainstream for whole the processes that we are doing in the municipality. Therefore we try to look at which aspect should be taken into account when a new area is developed or when a new spatial planning is started. In that way it is also beneficial to combine adaptation and mitigation together with other number of sustainability aspects into one sustainability challenge for the plan or for the area. In that way we don't have to bother the people who are working in such process by first time coming to tell them "You have to do this for adaptation". One week later someone come to tell them this should be for mitigation. And other weeks, this should be for the noise and this should be for the air pollution. So if you can combine them, your story is also stronger. Then you can easily try to make it a normal aspect of the procedure. So this process of mainstreaming is also helping to combine the aspect.

Q5: Have you ever met any difficulties when you are trying to combine mitigation and adaptation?
A5: Yes, we do meet difficulties. Actually, we also meet difficulties in mainstreaming as well mitigation and adaptation in the normal procedures. We have a number of examples where for instance adaptation is

been taken into account from the very beginning of the process, like in Heijplaat. There is a good study been done about different adaptation strategies for that area. It is taking into account that can be developed for the area. But there are also a number of examples where we have not yet succeed in this position, and the adaptation and mitigation is taken into account from the very first beginning. I think the challenge is even more to mainstream sustainability as such than the different combination of adaptation and mitigation. Perhaps we can even say adaptation and mitigation can strengthen each other, but we are also looking at how adaptation, mitigation and sustainability can strengthen the economic developments of an area or the economic strength of the City of Rotterdam. So we try to look at the win-win situations from sustainability, liveability and economic strength. In that way, we are trying to combine and to get further. In that process we are fully in now but it is not always, we are not there yet. There is a lot to do to make sure this normal way to taking into account.

Q6: You have explained you met some difficulties to mainstream mitigation and adaptation in the planning process. What exactly the problem is, maybe financial problem or..?
A6: Well, there are two main problems I think. One is financial. Because when the planning process is started and if there is someone saying we should do research for mitigation/adaptation possibilities in this area. Then we have a discussion that who will be paying for this research. Another one is that many planning processes are very tightly planned. They have not much time to spare; many times they are under high time pressure. The project managers will suspect this kind of investigation and research will anyway delay the process. They will not be willing to let it take part of this planning process

Q7: So it is decided by the project manager whether he/she want to mainstream mitigation or adaptation in the certain plan?
A7: This person has a key role. On the other hand, it is the [district chief] who says that we should have in this area a higher ambition on sustainability will be leading. The colleagues have to agree on that and they have to take position on it. Then it will be carried out. But even then, finance should be arranged and organised. It is a process where we also are busy with to make sure that the colleagues are also stating what they want, what the ambitions are at the aspect of sustainability. So that is stated and it is a good starting point to integrate adaptation and mitigation and so on in the process. But even then, when it takes number of years and there are difficulties. Then still there is a chance there something is been dropped. Because they are confront with too much difficulties and resistance from the market or whatever.
So then still needs to be monitored how far the mainstreaming is. We are at this moment trying to find which moments are crucial and how can we develop some instruments and tools to make sure that the sustainability is still part of the challenge in the planning process.

Q8: As you mentioned your team is a combination of mitigation project and adaptation project. Are there any other teams are like your team?
A8: Yes, the actual project organisation, Rotterdam Climate Initiative and Rotterdam Climate Proof, is now a combined and integrated bureau where a number of people are dealing with adaptation and a number dealing with mitigation; and there is also organisation in plan where other people who are dealing with air quality or noise abatement. So…an integrated team.

Q9: So within the team, there are some people working on mitigation and some people working on adaptation. Do they interact to exchange opinions in their own view from certain side?
A9: In the Rotterdam Climate Initiative, the overlap is very little. In my team, there is some overlap because some people are doing both mitigation ad adaptation. But I do think that we still have some chances trying to localise all the opportunities that we have get to learn from each other. I think it is worthwhile to deliberate that. So the question is correct I think. There is still some room for improvement in our organisation.

Q10: What can be the solutions for improvement?
A10: I think a clear statement from colleagues will help a lot. It is also that specific that they state what their ambition is for adaptation and mitigation for each area which will be developed. If there is statement and they want this ambition, then we will ask at the end if we are managed to do that. Then it will be incentive to mainstream it but also to find the synergies. Because these are always limited amount of money so in the way which we can use one measure for a number of purposes will always been engrave. So I think clear ambition from the colleagues will be helpful and even necessary.

Q11: You have mentioned several examples showing there are win-win situations. But have you ever met or saw any situation that it cannot create synergy but actually conflicting to each other?
A11: Yes, there are situations where it will be conflict. First of all, there will be the competition on limited finance and capacity, it will always be there.

I can think of other situations where there is sort of conflict as well. For instance, building wind energy, wind mills, many times it is done at the surface where it is on the edge of land and water. From planning point of view, it is a favour place. But sometimes, it would be easily in plan to put the wind mills on the dike or in the dike. Then the organisation which is for the dikes says, "We don't want to take risk. Because of the water safety is first and then sustainable energy next. We don't want to take any risk for it. So, no wind mill in the dike." It can be a sort of conflict between adaptation measure and mitigation measure.

And of course, building things as an adaptation measure, for instance, making the dikes higher will require a lot of energy and the soil has to be transported. So it will cost a lot of energy to build such thing. In that ways, it is conflicting.

I can't think of really many examples in a conflicting way, there sure they are, but…

Q12: Maybe we can think of the outcome of the measures. For example, I have read from papers which mention that from mitigation point of view, urban planning should create more condense, more building density to reduce the transportation volume, but it actually result in urban heat island effect. This can be kind of conflicting. If we think from this direction, maybe you have other examples?
A12: Well, which is also a conflict you might say is using the cooling of buildings with air-conditions units. It is actually transport the heat from inside the building to outside the building. Therefore also creating more heat stress whereby other people suffer from the heat and also are implying to buy air-condition. Then it is kind of spiral going up.

I was also thinking of transport. In adaptation, transport of water is also a good way of transporting. But the conflict is not necessarily because transport if water might be as energy efficient as by road at least when you get a full boat. I was also trying to look at other types of fuel or electric transport which can be applied for water.

What another conflict is the cooling capacity of the energy plant. When there are a lot of energy demands because of the hot summer. Many people want to cool their houses. The energy plant has to work hard. To cool this plant normally takes river water. But the river is also heating up; there is some kinds of limit where you are not allow using the river as a cooling medium anymore. Especially when it is very hot, The River is Low in the summer. Then it might be kind of problem for the electricity plant to use it as a cooling medium.

I was also thinking of using the groundwater as a way of energy storage. You can collect the heat in the summer and add it to the groundwater. And put it in the layer, about 40 meters deep or something. Then extracting the warm water in the winter again, using that heat to heat your building. The cold water that you are left with, put them up the spot. Then you can use the cold water in the summer to cool your house. Such system can also be combined with the water storage as long as it is deep enough, you can store the heat at bottom of the pool. But it is not a conflict, it is another win-win way

And building of the floating houses and building, I am not sure if it is a win-win or a conflict. I think you can use the water where the house is floating on as storage of heat, or to gain heat or energy from it. But then it has to be a light construction. So isolation might be something to take care of. On the other hand, the water is more moderate temperature during the year. So you don't have to cool or heat as much as normal land expose. I'm not sure; this is just thinking a loud.

Q13: Actually I have a question but maybe it is not relevant so much. The building isolation is done by designing the space inside the building to keep the air stay in the building for a long time. So the cold air will be kept inside in the summer. Is this designing also keep cold air inside the building in the winter?
A13: In that case, it keeps the warm air in the building. It keeps heat or cold in the building that is actually the main thing. So in the winter, a good isolation of your building helps the temperature gradients. Outside is cold and Inside is warm, helps to keep it intact. So without having too much energy needed for keeping this temperature because we don't lose so much heat through the façade of the building.
In the summer, if you keep the windows closed, then the heat is outside, the cold is inside, there is also a temperature gradient. It can be kept a live without using too much energy for cooling. In that way, isolation just helps to differencing temperature inside and outside, to keep it without using too much energy to do that.

It could also be done by having a large building mass which stores the heat or which takes a long time to raise the temperature when there is heat from outside. But then the disadvantage it also takes a long time after heat wave, to cool down again. So makes it steady, a bit slower but also longer.

Q14: So for a few innovations like the floating buildings, for now, you are not very certain to say it can create win-win situation or it might create conflicting situation. It depends on construction.
A14: Yes, I think you can create them but it needs attention. It is not automatically. But then it is also a way of building which is more flexible than normal type of building, a house, where you can also transport to another area if you want. It might be interesting to have a research did in some mean that this building can be used longer because it is more flexibility in the place we are going to put it. But we are now too short for that to say anything.

Q15: Another new thing for me is that you have mentioned the underground heat and cold storage. Have you ever think if you are too relying on this kind of measures. You might meet with more vulnerability. Like some people might say if people too rely on certain energy facility. If this energy facility was damaged or destroyed by these kinds of climatic impacts, it is also an additional vulnerability. So when you are designing this kind of infrastructure, like the heat and cold storage, did you ever think from this direction?
A15: I think if you talk about the vulnerability, you also have to look at the types of vulnerability from the centralised system or decentralised system. Also the central energy electricity plant has types of vulnerability, not only for climate change. As I just mentioned, in heat summer, perhaps it is not able to get rid of heat because the cooling water has already full, which happened in 2003. Also you might say it can be vulnerable for the terrorism or other actions like that, which can then have enormous impact on

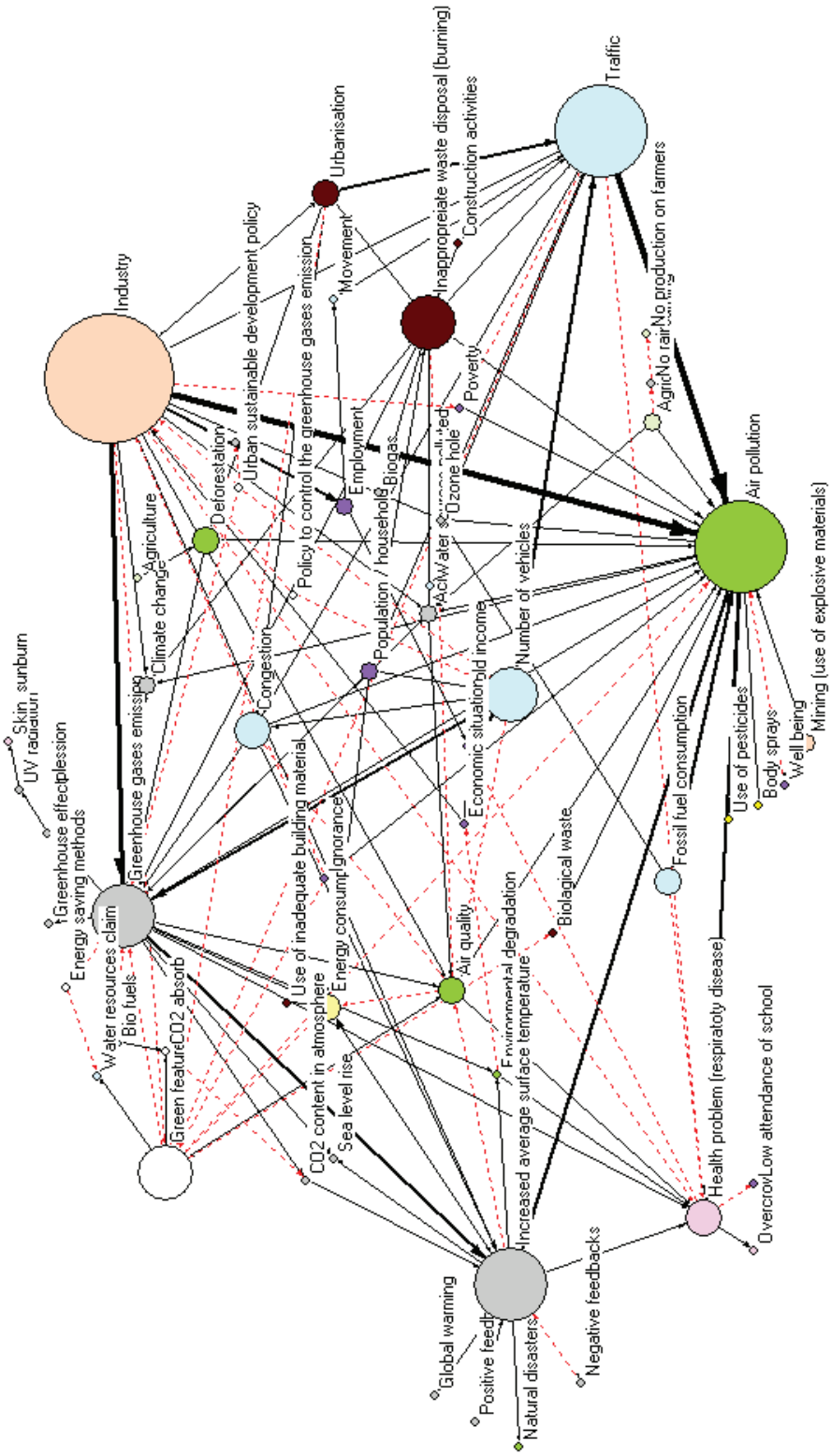
the whole area. No one will have electricity because the central plant had been destroyed. If you look from that point of view, it might a strategy to divide your risk on number of systems where always one or two will still keep functioning. That might also be part of the development which is already going on.

Perhaps in more decentralised ways of producing energy on houses themselves, for instance, with the photovoltaic or the heat collector on your roof or small wind mill or heat and cold storage. A number of types of energy sources are possible to be used. I think that is also direction going on where these types of energy generation are decentralised. But number of aspects will still be centralised, for instance, the coal plant electricity generator will be centralise because you want to collect the carbon from the chimney. Therefore it is efficient to have it centralised. Also the large wind farm is much more efficient to have them centralised than scatter over the landscape.

So a Number of electricity or energy forms I think they will still be in the centralised form, but a number will be decentralised. In that way, it will also divide the risks of having a break down or whatever it might cause.

Specific for heat and cold storage. I think the risks are not been able use because of climate change, will not be very high risk. Because the temperature is quite steady, average of 11 degrees during the year. So what you do with this kind of system is to add heat at a certain place and add cold to a certain place. Then some place might become 17 degrees, the other place might become 6 degrees. That is heat or cold you are using to heat or cold your building. You have to meet a balance for that. If you have more demand for cold than for heat then you have to add cold during the winter time. So we have to remain the balance anyway, because to climate change the demand for cold will decrease. It means you have to load more cold in the winter time than before. But you can still use the system. In that case, the vulnerability might more be after 30 years later. You might still be able to use your holder and filter in the system. After number of time you have to regenerate them, but that is normal thing and depending on the climate change.

Appendix II. Mitigation Preliminary Map



Appendix III. Adaptation Preliminary Map