Institutional interactions in climate adaptation of interdependent transport infrastructures

The case surrounding the Port of Rotterdam

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Institutional interactions in climate adaptation of interdependent transport infrastructures: the case surrounding the Port of Rotterdam

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Summary

Transport infrastructures that connect ports to the hinterland are important enablers of economic growth and development. Climate hazards may lead to substantial economic costs associated with infrastructure replacement and repair, and numerous broader implications, given the concentration of populations, assets and services associated with ports. The risks associated with climate change made governments on all scales increasingly aware of the fact that there is a level of unavoidable climate change that society must cope with, regardless of future emission trajectories. Therefore, infrastructure owners and governments on different levels are engaging in climate adaptation to adapt transport infrastructures to actual or expected climatic hazards. The behaviour of the actors involved in climate adaptation is guided by rules, norms, and strategies, referred to as institutions (Scott, 1995). Existing research on the institutional dimension of climate adaptation had exclusively focussed on studying institutions in isolation from each other. Researchers tried to understand whether existing institutions allowed and encouraged actors to develop and realize adaptation strategies, and as a result, enhance the adaptive capacity of society.

However, the connectivity and interdependencies between institutions that guide actors had not been studied. Moreover, no method that systematically mapped and showed these institutional complexities had been used. The goal of this research was therefore to systematically track institutional interdependencies in climate adaptation of transport infrastructures around ports for two purposes. First, to formulate policy recommendations for governments, infrastructure owners, and the private sector based on insights in the connections and interdependencies between institutions. Second, to track the relations between institutions in a *systematic* manner with a method devoted to identifying and mapping them.

The case which was considered was the Port of Rotterdam and the infrastructures connecting the area to the hinterland. The Port of Rotterdam is a point of convergence between various transport infrastructures, namely roads, rails, waterways, and pipelines. Disruptions due to climatic hazards in one infrastructure may propagate to the other infrastructures, resulting in network-wide failure. Identification of the institutions that connect actors in climate adaptation decision-making processes is therefore crucial to understand their power positions, responsibilities, and (resource) dependencies. Moreover, doing this in a systematic manner provides future analysts with a procedure or tool to better understand the institutional complexities in other policy-making contexts.

For these purposes, a conceptual model was constructed which consisted of three theoretical building blocks. First, the Grammar of Institutions (ABDICO syntax) was used to formalize three types of institutions, namely rules, norms, and strategies, as institutional statements (Crawford and Ostrom, 1995). Second, the Institutional Analysis and Development (IAD) framework was used to depict decision-making spaces (action arenas) in which actors interact (Ostrom, 2011). Third, the social network paradigm was used to link institutional statements together in each action arena.

Institutional Network Analysis (INA) and scientific contribution

Together with these theoretical building blocks, the prototype of the Institutional Network Analysis (INA) method (Ghorbani et al., 2020) was improved and applied to the case study. First, data was collected on the institutions that guide actors through desk research and 16 semi-structured interviews with infrastructure owners, government agencies, and private businesses in the Port.

After writing narratives by coding and clustering the data, institutions were identified from the data and formalized with the ABDICO syntax. While existing literature had given steps for formalizing institutions with the ABDICO syntax from written documents, no such steps existed for interview transcripts. The format of interview transcripts is different than that of laws, regulations, and policy documents, making it more challenging to formulate institutional statements. Therefore I proposed a series of steps to help future researchers in the formalization of the institutions. It draws from the examples of Watkins & Westphal (2016) and my own experiences in deriving institutional statements from the interview transcripts.

The institutional statements were connected to each other to form Institutional Network Diagrams (IND). Within these diagrams, the connections between institutional statements are graphically represented for the three stages of climate adaptation surrounding the Port of Rotterdam: knowledge gathering, conducting risk dialogue, and drawing up an implementation agenda. The connections explicitly show which actor, and corresponding institutional statement, influence or activate other institutional statements and the actors to which they apply. From the INDs, there are four additional forms of analysis that further support the formulation of policy recommendations. First, one can analyse institutional conflicts, when two or more institutions with different outcomes guide actors' behaviour. Here, institutional hierarchy comes into play since in reality, actors may choose and give prevalence to one institutional statement over the other(s). Next, different network metrics, such as density, centrality, and embeddedness, provide information on the spread of information, and the position and involvement of actors in a network. Furthermore, it is also possible to look at connections between institutional statements in different INDs rather than connections between institutional statements within a single IND. Lastly, I proposed the construction of aggregated formal charts based on the INDs to better understand the power positions of actors in each IND.

Recommendations for better climate adaptation of transport infrastructures

Based on the analyses, I recommended that infrastructure owners, government agencies, and the private sector shift the focus of their research efforts to drought and heat, and engage in more collaborative research, primarily to assess the impacts of one infrastructure failure on the other infrastructure. Furthermore, formal clarification is needed from the Ministry of Infrastructure and Water Management on the financial responsibilities of actors operating in outer-dike areas. Moreover, I recommended that a wider range of actors beyond the area directly connected to the Port should be invited to the risk dialogues to provide information on infrastructure risks. This would help to broaden the scope of climate adaptation to entire supply chains that are dependent on these infrastructures. Lastly, I recommended to make the formulation of a common risk assessment framework a fixed part of the risk dialogues for adequate weighing and prioritizing of short-, medium-, and long-term impacts of climate change.

Recommendations for future research

Based on the findings of the study, several key recommendations for future research were formulated. These included improving the graphical elements in the INDs to explicitly convey information on the cultural, and political forces that impact actors in their decision-making by visualising important objectives they have in mind. Moreover, for overcoming individual bias and enabling comparison of different interpretations of institutions, it is was also recommended that future researchers conduct the coding, clustering, and formalization of institutions in teams. To improve the formalization process, the series of steps for identifying institutional statements in interview transcripts also ought to be used in other case studies to improve their application. Lastly, it was recommended to use the INDs alongside various modelling tools to study the institutional dynamics in climate adaptation.

Acknowledgements

In the name of God, the Compassionate, the Merciful,

توانا بُوَد هرکه دانا بُوَد

Capable is he who is wise

Ferdowsi

Never had I expected that I would write a master thesis under such exceptional circumstances. I went from going to the library and my internship, to working from home on a project for six months. Initially, you feel isolated from the rest of the world, and yet you have to adjust to a completely new way of working and living due to the coronavirus. This is overwhelming, but gradually, you realize that you are not alone, and that they key to completing your master thesis is reaching out to others, whether it is for constructive feedback, or for checking on each other. Luckily, I had many people around me who helped me in completing my research.

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Batoul Mesdaghi

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1. Introduction

1.1 Climate change: from mitigation to adaptation

Urban areas serve as important hubs for social and economic advancement – generating around 60 percent of the global GDP (UN, 2019a). In this respect, transport infrastructures are critical for integrating nations to the world economic market. This is especially the case for transport infrastructures which are connected to port areas, since 80% of trade is carried by sea (Becker, Acciaro, & Asariotis, 2013; Dwarakish & Salim, 2015). The great significance of ports' transport infrastructures for economic trade also implies that they are very vulnerable to the impacts of climate change (Wamsler, Brink & Rivera, 2013). Risks for transport infrastructures lie in limited availability and physical damage due to extreme rainfall with strong gusts, periods of droughts, and flooding for example (Rijkswaterstaat, 2019). These effects lead to serious disruptions in transport operations with costly ramifications, and broad implications for international trade (Becker et al., 2013).

Initially, policy development for coping with the risks of climate-related hazards was dominated by a focus on climate mitigation only (Preston, Westaway & Yuen, 2011). Climate mitigation aims at reducing the emission sources or enhancing the sinks of greenhouse gases. However, institutions on many geo-political scales have given increased attention to the identification and implementation of climate *adaptation* policies (Birkmann, Garschagen, Kraas & Quang, 2010; UN, 2019b). This shift can be attributed to increasing awareness of how vulnerable social and environmental systems are, and to the willingness to commit to a level of unavoidable climate change regardless of future emission trajectories (Preston et al., 2011).

Climate adaptation focusses on the "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects" (Locatelli, 2011, p. 1). Depending on the initiating industry, adaptation policies can be public or private. Furthermore, adaptation strategies can be classified as planned or spontaneous, where the former is the outcome of public policy decisions, and the latter knows no specific policy as regulation beforehand (The World Bank, 2010). Both on the short- and long-term, there are hard and soft adaptation measures one can undertake. Hard adaptation measures are characterised by capital intensive, large, complex, inflexible technology and infrastructure, while soft measures prioritize community control (Sovacool, 2011). In climate adaptation, it is important to note transport infrastructures are not isolated from each other, but that interdependencies exist between them. Disruptions due to climatic impacts in one infrastructure may propagate to the other infrastructures, resulting in network-wide failure (Bollinger et al., 2014). An example would be when extreme weather disrupts railway operations, and results in more occupied roads.

The functioning of transport infrastructure therefore pre-supposes coordination of the climate adaptation measures taken by public and private parties who manage and use these infrastructures (Koppenjan & Groenewegen, 2005). This is because there needs to be a common ground on what the climatic impacts are, and how different infrastructures are to be adapted. Adaptation measures are shaped and implemented through processes of *governance*. Governance refers to "processes of interaction and decision-making among actors involved in a collective problem that lead to creation, reinforcement, or reproduction of…*institutions*" (Hufty, 2011, p. 405). Governance is therefore related to the ways that actors are steered and steer others in their climate adaptation efforts.

The resulting *institutions* from these governance processes play a central role in organizing the behaviour of actors, and with that, the adaptation of transport infrastructures (Brunner & Enting, 2014; Roggero, Bisaro & Villamayor-Tomas, 2018). Institutions are not to be confused with organisations. Ostrom defines institutions as the "shared concepts used…in repetitive situations organised by rules, norms, and strategies" (Basurto, Kingsley, McQueen, Smith & Weible, 2010, p. 523). In this definition, the organisations shape and are influenced by institutions. Here, institutions are of three kinds: rules, norms, and strategies. Rules are different from norms and strategies since they have tangible sanctions in legislation. Strategies are different from rules and norms since they are not created or enforced by other actors, as contrary to rules and norms. By attaching meaning and normativity to particular situations, institutions govern the strategic policy-making choices of actors and stabilize decision-making to somewhat predictable paths. This does not imply that institutions never change, but that dramatic changes in strategic directions are countervailed (Siddiki et al., 2019; Zhang, Ng & Becker, 2017).

1.2 The institutional dimension of climate adaptation

To understand how institutions affect climate adaptation efforts of transport infrastructures, researchers first studied whether impacts of climate change on the vulnerability and resilience of transport infrastructures are known to various stakeholders (subsection 1.2.1). Then, they studied the role of institutions in current climate adaptation practices (subsection 1.2.2).

1.2.1 Vulnerability and resilience of transport infrastructures for climate change

A large share of the contributions in existing literature provide insights into the influence of climate change on transport infrastructures connecting ports to the hinterland (Roggero et al., 2018). In this respect, the focus is either on the risk exposure (vulnerability), or the resistance and recovery (resilience) of transport infrastructures (Ruiten, Bles & Kiel, 2016). Major consequences of climate change in resilience studies are sea-level rises, river flooding, and urban heat by using numerical modelling and GIS software (Ehsan, Begum, Nor & Maulud, 2018; Gracia et al., 2019). Other authors develop consistent methodologies for quantifying and evaluating vulnerabilities and risks (Messner, Moran, Reub & Campbell, 2013). An overview of the biophysical impacts often includes estimations of economic consequences for different infrastructures as well (Wise et al., 2014). For waterways, different authors determine the cost for maintenance of service standards given the changes in climate patterns for OECD countries (Hughes, Chinowsky & Strzepek, 2010; Jonkeren, Rietveld, Van Ommeren & Linde, 2013). Similar studies exist for road infrastructures (Axelsen & Larsen, 2014; Chinowsky, Price & Neumann, 2013), rail networks (Doll et al., 2013; Lindgren, Jonsson & Kanyama, 2009), and port infrastructures (Esteban, Webersick & Shibayama, 2009; Yang et al., 2018). Other studies extend their scope to include social impact indicators as well, such as workforce health, safety, and employee absenteeism (Gasper, Blohm & Ruth, 2011; Stenek, 2011).

1.2.2 The study of institutions in climate adaptation

Extensive research thus exists on the effects of climate change and their impact on transport infrastructures surrounding ports. Researchers then turned to senior port managers, policy advisors, and infrastructure owners to study the assumptions underlying long-term plans, public-private collaborations for climate adaptation, and the current preparedness of infrastructures for climate change (Ng, Chen, Cahoon, Brooks & Yang, 2013). This was done in workshop sessions (Becker et al., 2012), surveys, or semi-structured interviews for in-depth case studies (Becker, Inoue, Fischer & Schwegler, 2012; O'Keeffe, Cummins, Devoy, Lyons & Gault, 2020). The studies reveal that these stakeholders show serious concerns about the way that climate change influences day-to-day operations for transport infrastructures and the supply chains they serve.

However, while the attitudes towards climate adaptation are positive, the resulting transformation of these concerns to actual response is often not translated in strategic planning (He & Ng, 2019). Climate adaptation has remained embedded primarily in institutions related to daily operating schedules, emergency procedures, and risk management (Ng et al., 2013; Smit & Wandel, 2006).

Researchers therefore looked closely to barriers in strategic climate adaptation (Dilling & Lemos, 2011; National Research Council, 2010). First, it was found that the rate of climate change requires new infrastructures to cope with a large range of changing climate conditions, making it more complex and expensive to design policies. Second, despite the insights in the risks that infrastructures face, there is a lot of uncertainty in future climate change. The results from a single climate model thus cannot serve as the sole input for infrastructure design (Hallegatte, 2009). Furthermore, a lack of coordination within and across government agencies, private companies, and nongovernmental organisations still enforces uncoordinated research efforts, and diverging risk perceptions (Sietz, Boschütz & Klein, 2011). All of these consequences are again barriers to a systematic approach to climate adaptation (Adger et al., 2009; Ng, Monios & Zhang, 2019).

Problems may also be present from an institutional perspective. These institutional problems vary depending on the actors (what is beneficial to one actor may be a barrier to the other) and the context (what is perceived as a barrier depends on the situation). As mentioned before, the institutions here are not the organisations that conduct climate adaptation, but institutions are the rules, norms, and strategies that the organisations follow. Often times, studies about the 'institutions' of climate adaptation focussed on the organisations themselves rather than the institutions they follow (Glaas & Juhola, 2013). Studies which do focus on institutions identify two barriers: a lack of flexibility in existing institutions, and an absence of legal mandates for climate adaptation.

Inflexibility of existing institutional structures

As mentioned before, climate change is uncertain with regards to the size and distributions of its effects (Tompkins & Adger, 2003). Authors therefore argue that climate change demands flexible forms of adaptation that can cope with these uncertainties (Folke, 2006; Smit & Wandel, 2006). These types of approaches recognize the dynamic character of natural systems and the importance of frequent monitoring, reviewing, and changing of policies as a result of new understandings (McDonald & Styles, 2014). This implies that cooperation between public and private parties, through experimentation, learning, and dialogue is crucial to find out which solutions are feasible and effective (Rietveld et al., 2013). However, existing institutions do not always enable decision-makers to account for or cope with the changing climate conditions and the learning processes which stem from adaptive approaches to climate adaptation (Lawrence et al., 2015). Water infrastructure planning rules for example might include rigid norms, and assume a non-changing climate (Bierbaum et al., 2013). Other times, institutions restrict or inhibit adaptation action from local government agencies. This is the case when roads within a municipality are under the control of the central government, which may limit necessary response when needed locally (Measham et al., 2011).

Lack of institutional structures

The lack of institutional frameworks particularly causes uncertainty in stakeholders' roles in climate adaptation (Bierbaum et al., 2013; Ng, et al., 2019; Ruiten et al., 2016). Since climate adaptation is a relatively new field, the exact responsibilities of the actors involved are often not clearly allocated and ambiguous (Mees, Droessen & Runhaar, 2012). This is because institutional change manifests itself due to informal and incremental learning experiences of parties that have interacted with each other in the past. These experiences are then translated into institutions because they had proven to function in the course of time (Koppenjan & Groenewegen, 2005).

In this way, institutions carry the bias of past interactions, power positions, and views (Klijn & Koppenjan, 2006). With little experience in climate adaptation, it remains unclear who should take the lead in adaptation and how institutions are to be put into place (Kretsch & Becker, 2016). Individual actors are thus forced to come up with management mechanisms for climate adaptation with little support from existing institutions. Actors interpret the few formal existing institutions to their own institutional learning and rely more on informal institutions, making it harder for formal institutions to eventually be established (Ng et al., 2019). Incomplete institutions also make it harder to link existing strategies of the port and required adaptation strategies (He & Ng, 2019; Zhang & Ng, 2016) and move to actual planning and implementation (Messner, Becker & Ng, 2016) even with more understanding of climatic predictions and impacts (Ford, Berrang-Ford & Paterson, 2011).

However, for identifying institutional barriers, it is not only necessary to look at individual institutions and how they enable or hamper climate adaptation. It is equally important that institutions are studied *in relation to each other*. An example is described in a case study of coastal management in Sweden (Storbjörk & Hedrén, 2010). The researchers described a collision between the Natura 2000 and the European Recommendation on Integrated Coastal Zone Management. These regulatory frameworks led to tensions in decision-making between those in favour of further exploitation of waterfront areas (e.g. allow attractive waterfront housing and rebuilding of harbour-areas) and those who wished to relocate these settlements away from risky areas. While this example does not directly relate to transport infrastructures, it shows how the trade-offs between policy-agendas, values and priorities were not adequately addressed and coordinated between the stakeholders involved in adaptation (Mutombo & Ölçer, 2017). It is recognized in existing literature that such tensions may arise when there are multiple institutions in place at the same time. These tensions are enforced when decision-making procedures of actors are not very connected, and as a result, their objectives and norms are not aligned with each other (Delmas & Toffel, 2003; Pittock, 2010; UN, 2014). Despite this recognition, these tensions are often times briefly written down in very general terms when studying a case (Glaas & Juhola, 2013; Well & Carrapatoso, 2016). Researchers have not developed and actively applied methods which systematically identify and map the relations between institutions, making it harder to study the connections and interdependencies between institutions (Ghorbani, Bosch & Siddiki, 2020).

1.3 Knowledge gaps and relevance

Climate adaptation is a relatively new field, with few preceding policies to learn from in institutional terms. When studying 'institutions' in the context of climate adaptation, studies define them as organisations, rather than the rules, norms, and guidelines that organisations follow. When the latter definition is considered, the relations between them are largely disregarded so that institutions are studied individually to see whether they support climate adaptation activities of actors. The relations between institutions, are only briefly mentioned in existing research (Mclean & Becker, 2019). There is no comprehensive method applied for systematically identifying and mapping the relations between institutions, making it more challenging to adequately understand institutional complexities. This research therefore assumes that adaptation efforts are ongoing, but that a lack of systematic identification of the relations and interactions between institutions hampers comprehensive adaptation efforts for different, interdependent transport infrastructures surrounding ports. This research therefore aims to be a first step towards a comprehensive approach to climate adaptation, by providing insights in the connections and interdependencies between institutions underlying climate adaptation. The societal relevance of this research is to track institutional interactions and dependencies to prevent unsystematic, individualistic and pluralistic climate adaptation efforts. The scientific relevance is to track the relations between institutions systematically with a method devoted to identifying and mapping them.

1.4 Research questions and approach

For the given purposes of this research, the following main research question has been formulated:

How do institutional interactions influence climate adaptation of interdependent transport infrastructures surrounding port areas?

In order to answer this main research question, four sub-questions have been formulated:

1. How can the relations between institutions be systematically identified?
2. Who are the actors involved in the climate adaptation of transport infrastructures surrounding port areas?
3. How can climate adaptation efforts be assessed by looking at institutional interactions?
4. How can climate adaptation efforts be improved based on an assessment of institutional interactions?

Sub-question 1 aims to relate institutions to each other so that their interdependencies can be studied and better understood. The primary foundation for relating the institutions to each other is a prototype developed by Ghorbani et al. (2020), called Institutional Network Analysis (INA). In order to make this prototype applicable, it is first necessary to establish a theoretical framework about institutions, and how they can be related to each other according to a network-approach as proposed in INA.

Sub-question 2 is then relevant for defining the scope for the analysis of climate adaptation through INA. An exploratory case study approach will help in defining the area of study for climate adaptation of transport infrastructures, and the actors responsible for the adaptation of the infrastructures. A case study is defined as a "empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly defined" (Yin, 2009, p. 18). Contrary to an experimental design, a case study approach does not seek to deliberately manipulate the environment to test a specific hypothesis. Rather, its aim is to explore an event or phenomenon in depth in its natural context (Crowe et al., 2011).

Yin (2009) formulated three conditions under which the use of a case study approach is particularly preferable. First of all, exploratory case study approaches lend themselves well for studying "how" and "what" questions, when there is no single set of outcomes. For climate adaptation, it is known that institutions are related to each other and that connections and interdependencies between them exist (Oberlack, 2016). However, existing literature has not systematically mapped these connections. A case study approach is an appropriate approach to understand how the institutions can be related to each other and what the relations between them are in a specific context. Furthermore, case studies are preferred when the focus of the study is on contemporary events as opposed to historic phenomena. Climate adaptation is an interesting field for case studies, because it is relatively new compared to climate change mitigation, and know a relative lack of preceding policies in its field. Lastly, a case study approach is preferred when relevant behaviour of actors cannot be directly, precisely, and systematically manipulated. Since the relations between institutions have not been systematically studied yet, it is difficult for researchers to pinpoint where exactly the behaviour of actors can be steered.

Therefore, it is important to explore the current institutions that guide their behaviour in the first place before one can come choose more experimental approaches.

As a case, the transport infrastructures connected to the Port of Rotterdam will be considered. The Rotterdam region was identified as one of the "hotspots" in the Netherlands which is particularly vulnerable to the impacts of climate change (Westerhoff et al., 2010). This was due to the presence of the Port of Rotterdam, and the important economic benefits it generates for the region and the Dutch economy. The Port of Rotterdam is situated near the sea, and at the same time lies in proximity of urban areas. Moreover, there is a multimodal transport infrastructure to and from its hinterland, which is particularly vulnerable to extreme weather events (Ruiten et al., 2016). Given the position of the region and the Port, it is crucial for infrastructure owners, the Port, and users of the infrastructure to have a mutual understanding of the institutional interactions for climate adaptation as a starting point to improve and align their adaptation practices.

Sub-question 3 aims to assess the performance of climate adaptation by focussing on the structure of the existing relations between institutions. For this purpose, desk research and stakeholder interviews will be conducted to gather data on the most important institutions and actors involved. Important narratives from the interviews will also be written down through discourse analysis to do justice to the richness of the information given in them. Next, the INA method will be applied to the case of the Rotterdam region and used to assess the performance of the existing institutional structures. Based on the analyses, a better understanding of the institutional connections is given, and one can formulate recommendations for improving climate adaptation efforts for transport infrastructures. This last purpose is captured in sub-question 4.

1.5 Structure of this thesis

Figure 1 depicts the research flow diagram for this study, with the sub-questions (SQ1-4) that the chapters relate to. Chapter 2 will focus on providing a theoretical foundation on institutions, their connections and interdependencies, and a framework for their analysis. This helps to shape the research method in chapter 3, namely, the INA method. Chapter 4 contains the application of INA on the case study. Chapter 5 gives policy recommendations based on the application of INA, answers the research questions, presents the scientific contributions of the study, and gives recommendations for future research based on the limitations of this study.

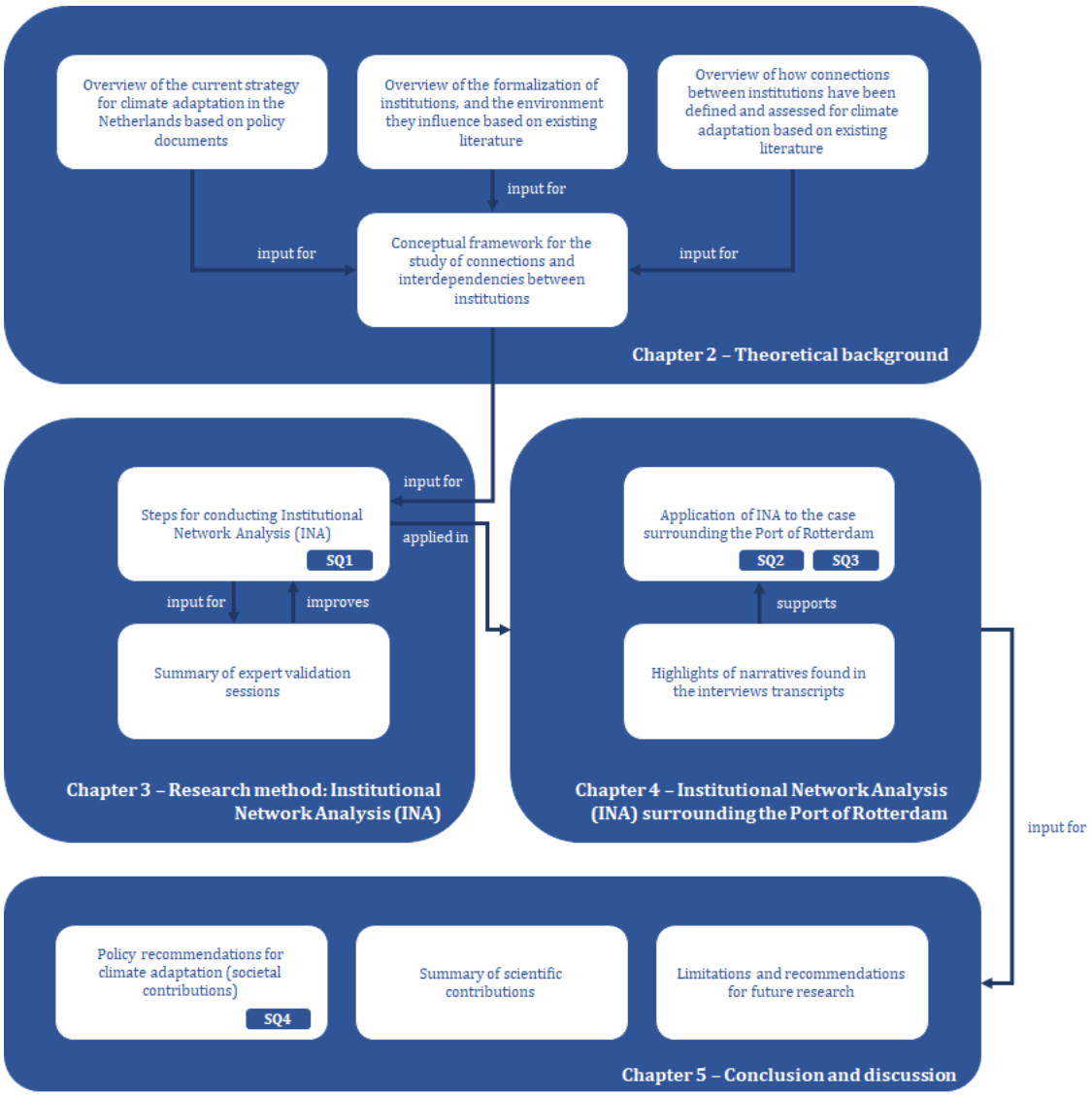


Figure 1: the research flow of this study

2. Theoretical background

This chapter provides the theoretical background to be able to study the connections and dependencies between institutions. In order to link the theory with the practice of climate adaptation in the case study, section 2.1 summarizes the national framework for climate adaptation in the Netherlands, to make a distinction between the consequent phases in which climate adaptation efforts are undertaken. In order to link this to institutional analysis, section 2.2 explores what institutions are and how they can be formalized. Section 2.3 looks at the connections between institutions. The conceptual framework for the analysis of the relations between the institutions is presented in section 2.4.

2.1 Climate adaptation efforts in the Netherlands

This section provides background information on the framework for climate adaptation in the Netherlands. The framework on climate adaptation in the Netherlands consists of two parts: the National Adaptation Strategy (NAS) (subsection 2.1.1) and the Delta Programme (subsection 2.1.2). The NAS is an overarching strategy on a national level, and aims to raise awareness on all possible impacts of climate change. The Delta Programme follows from the NAS, and is a cooperative effort between all layers of the Dutch government. Its focus is mainly on the development of spatial measures for problems related to fresh water conservation, water management safety, and spatial (climate) adaptation (Ministry of Infrastructure and Water Management, 2018).

2.1.1 The National Adaptation Strategy (NAS)

The political and scientific focus in the Netherlands shifted towards climate adaptation after near floods occurred in the Rhine river basin in 1993 and 1995. Until then, traditional technical interventions like dike reinforcements and water-pumping out of polders had been undertaken to counter the effect of extreme weather and sea level rises (Swart et al., 2009). The then Ministry of Housing, Spatial Planning and Environment organised a national congress for the development of more a comprehensive national programme for climate adaptation. The first climate adaptation strategy of the Netherlands was published in 2007, after compiling information on climate impacts, vulnerabilities, and possible governance strategies for climate adaptation (Westerhoff et al., 2010). After the first climate adaptation strategy was published in 2007, regional meetings, advisory boards, and national research programmes were initialized to elaborate on the details of this strategy. It was found that the adaptation strategy needed to be more comprehensive and that vital infrastructures required special attention (Ministry of Infrastructure and the Environment, 2016). Examples of vital infrastructures are energy and ICT-networks, but also transport infrastructures in the Netherlands (PBL, 2015). This led to the adoption of the second National Adaptation Strategy (NAS) of the Netherlands in 2016 by the Council of Ministers. According to the NAS, the risks of climate change for the economy, living environment, and well-being of society for all the sectors in the Netherlands have to be examined and coped with (Ministry of Infrastructure and the Environment, 2016, p. 6). Transport infrastructures are included as one sector. Transport infrastructures include networks of roads, rails, waterways, airports, sea ports and pipelines. Often times, they depend on other networks such as energy and IT. There are four overarching categories of climate impacts risks included in the NAS: waterlogging, heat stress, drought, and flooding due to sea-level rises (Kennisportaal Ruimtelijke Adaptatie, 2020a). For each climatic impact category, potential impacts on infrastructures are shown in Table 1.

Table 1: the impacts of climate change on infrastructures as formulated in the NAS.

Impact category	Potential impacts on infrastructures
Waterlogging	- Reduced operability of infrastructure die to more extreme weather (e.g. frequency and intensity of strong wind gusts, thunder and hail). - Restricted navigability on inland waterways. - Faster deterioration of infrastructures due to precipitation peaks. - More accidents (but of less severity) due to increase in peak precipitation. - Increased risk of flooding.
Heat Stress	- Greater risk of expansion and deformation of rails and bridges and melting of asphalt. - Decrease in use of road salt. - Fewer accidents and fatalities due to ice on the roads. - Less ice-disrupting waterborne transport.
Drought	- Increased risks of forest fires and roadside fires. - Restricted navigability of inland waterways. - More difficult loading and unloading of vessels. - Increased risk of damage and higher maintenance costs for infrastructure and the built environment.
Sea-level rises (floods)	- More difficult loading and unloading of vessels. - More closure of the Maeslantkering storm surge barrier, causing disruption to shipping. - Decreased availability of fresh water. - Failure of vital and vulnerable infrastructure due to flooding.

The NAS also outlines the consequences these impacts may have. The direct consequences are mainly economic losses. Evident examples are road accidents or when the capacity of infrastructures is reduced due to precipitation. Other examples include the flooding of tunnels, disruptions in trains services, and temporary navigability restrictions on inland waterways. Indirect damages include impacts on other sectors and infrastructures elsewhere (e.g. cumulative effects). The NAS therefore aims at raising awareness about the most important climate change impacts among a range of parties. It also encourages regional and lower levels governments to convert the findings in the strategy into more concrete objectives, actions, and allocation of tasks and costs by taking the important climate change impacts in the NAS into account in local policies.

2.1.2 The Delta Programme

When the first NAS was published, it was concluded that water functions and vital networks required special attention. This is why the Delta Programme was initialised in 2010 (Ministry of Infrastructure and the Environment, 2016). The national government, provincial and municipal authorities, and the water boards in the Netherlands are all involved in the programme and work closely together.

Private businesses, safety regions, and non-governmental organisations are also involved in providing input for the development of plans in the Programme. The Delta Programme focusses on climate adaptation on three important topics, called Delta Decisions (Delta Programme Commissioner, 2020a):

1. Water Safety: protecting civilians and the economy against floods;
2. Freshwater Supply: reducing water shortages and optimise freshwater usage for the economy and public utility functions;
3. Spatial Adaptation: realising water-robust and climate-resistant spatial planning in built-up areas.

Additionally, the Delta Programme looks at the fresh water conservation and safety in Rijn-Maas delta area and Ijssel-lake area. Overall control of the Programme is exerted by the Delta Commissioner, under the Ministry of Infrastructure and Water Management. Every year, the planning for the years ahead for the Delta Programme must be presented to the House of Representatives in the Netherlands as part of the annual budget of the Ministry of Infrastructure and Water Management (Delta Programme Commissioner, 2020b). The plans contain measures which will be taken by the parties and the budget to be allocated.

Figure 2: the seven ambitions which structure the Delta plan on Spatial Adaptation in the Netherlands (Bauer, Feichtinger & Steurer, 2012)

Each Delta Decision has an elaborate Delta Plan and a Delta Fund. The ambition in the Delta Decision for spatial adaptation is that *the Netherlands is water-robust and climate-resistant in 2050* (Delta Programme Commissioner, 2020c). This implies that spatial measures need to be developed to be able to cope with the four overarching categories of climate change consequences as formulated in the NAS (Kennisportaal Ruimtelijke Adaptatie, 2020a). In order to determine what is "water-robust" and "climate-resistant", seven ambitions, or phases, have been formulated and published on the online platform for the Delta Plan on Spatial Adaptation (Figure 2). Governments on all levels aim to conduct the first three ambitions, or phases, of the Delta Plan before the end of 2020. For this, municipalities, water boards and provinces work together in around 40 working regions and 7 regional consultation groups (Delta Commissioner, 2018). The first three consequent phases are: mapping out vulnerabilities (knowledge gathering), conducting risk dialogue (and drawing up a strategy), and drawing up an implementation agenda.

Mapping out vulnerabilities (knowledge gathering)

The first phase in the Delta Plan is to map the future vulnerabilities for the both rural and urban areas in the Netherlands. An initial, national or regional exploration of the primary and secondary effects of climate change can be done through "climate impact atlases". Examples of primary changes in the climate are temperature and precipitation changes. Secondary impacts result from these primary changes: higher temperatures may lead to water shortages for example. The climate impact atlases consist of a series of maps with scenarios of the Royal Dutch Meteorological Institute (Klimaateffectatlas, 2020). While these maps show the effects of climate change by comparing the current climate with the climate scenarios, they do not depict regional and local vulnerabilities to a great level of detail for transport infrastructures. However, the climate impact atlases serve as a good initial overview of the effects that different regions and municipalities may experience and can be used as input in the development of more detailed "stress tests" (Kennisportaal Ruimtelijke Adaptatie, 2020a). Stress tests allow for the mapping of vulnerabilities on regional and local levels for the four overarching categories of climate change consequences as formulated in the NAS (Table 1). Every six years, the stress tests are updated based on new climate change scenarios of the Royal Dutch Meteorological Institute. Stress tests are to be carried out on a national level, regionally by provinces and water boards, and locally by municipalities. To safeguard the uniformity between the different stress tests as much as possible, the platform of the Delta Plan Spatial Adaptation has published several standards for the procedure of carrying out the stress test (Kennisportaal Ruimtelijke Adaptatie, 2020a). It does not prescribe the whole procedure in detail, neither does it give guidelines for the evaluation of the quality of the stress test. Rather, the platform of the Delta Plan advices parties on their underlying assumptions, input data, calculations, and approaches to communicating the results of the test (Ministry of Infrastructure and Water Management, 2019). It is recommended that parties work according to these advices as much as possible and motivations for deviating from them are explicitly mentioned in the reports of the stress tests.

Conducting risk dialogue (and drawing up strategy)

The results of the stress tests serve as important input for risk dialogues. During risk dialogues, public and private parties discuss the severity of the climatic risks found in the stress tests and other forms of research. A risk dialogue can be conducted in many different forms: it may consist of a dialogue between citizens and municipalities in their own neighbourhood, but also a series of workshops with national infrastructure owners for example. Therefore, the platform of the Delta Plan on Spatial Adaptation has formulated a set of guidelines that provide information on the expected course and outcomes of risk dialogues (Kennisportaal Ruimtelijke Adaptatie, 2020b). During a risk dialogue, the parties operating in a working region generally present the key findings from the stress tests first. Parties then negotiate to establish a common ground on the most critical risks to be tackled. Based on the priorities in climate risks, a brief strategy will be formulated which contains information on how to proceed after the dialogue on the short- and long-term. The strategy may contain potential measures, and a brief division of roles and responsibilities of actors for looking into the implementation of potential measures selected during the risk dialogue. Risk dialogues can also lead to the construction of additional stress tests or other forms of research if found necessary.

Drawing up implementation agendas

Based on the outcomes of the risk dialogues, a more specific implementation agenda will be set up which includes the planning and budget for measures to realise the ambitions from the risk dialogues.

2.2 Institutional analysis

In this section, I provide information on institutions. I focus on which types of institutions exist (subsection 2.2.1). Furthermore, I describe how institutions can formalized and what the system in which guide the behaviour of actors looks like (subsection 2.2.2).

2.2.1 Types of institutions

According to Scott (1995), there is no singular, universally accepted definition of institutions. In existing studies, the emphasis is often put on the distinction between formal and informal *rules* that guide and shape the behaviour of actors (Roggero et al., 2018). Formal rules are written as constitutions, laws, rights, and regulations that are enforced by official authorities, while informal rules are unwritten customs that shape the though and behaviour of actors (Berman, 2013; Brunner & Enting, 2014). The sole emphasis on rules in defining institutions is problematic because this would imply that in a social setting, there are no influencing forces other than rules (Watkins & Westphal, 2016). Scott (1995, p. 33) gives a more comprehensive distinction, and defines institutions as "cognitive (strategies), normative (norms), and regulative (rules) structures and activities that provide stability and meaning to social behaviour". Apart from rules, social behaviour is also guided through and shapes norms and strategies. The carriers of these institutions can be cultures, structures, and routines (Table 2).

Regulative systems (rules)

Most scholars study institutions from a regulative perspective. Institutions from a regulative perspective are characterised by the processes of explicit rule-setting, monitoring activities, and sanctioning activities. They lead to a system based on coercion. When actors do not conform to the established rules, they can be punished through legal, tangible sanctions. This creates a certain stability because actors feel that they *have to* comply, because there is a legal obligation. A system of explicit rules and referees controlling compliance is much in line with the concept of rationality. The idea is that humans, as rational beings, pursue their interests according to a cost-benefit logic. Compliance results from an instrumental interest and expedience to new explicit rule systems.

Normative systems (norms)

From a normative perspective, institutions bring a prescriptive, evaluative, and obligatory dimension into a social setting. As opposed to regulative systems, one does not comply to institutions because of an instrumental interest, but because of appropriateness, and normative expectations which put external pressure on actors. Actors do not have to comply like in regulative systems, but *ought to* comply given the present values and norms (Palthe, 2014). Values are conceptions of what is preferred or desirable. These conceptions are expressed through certain standards to which existing structures and behaviour can be compared. Norms specify how things should be done to pursue valued ends. Normative systems thus specify the goals and objectives one wishes to reach, as well as the appropriate paths to realizing them. Sets of values and norms are prescriptions, or conceptions of appropriate action, which can apply to all actors, or be specific to certain actors only ('roles'). Behaviour is therefore morally governed, through the existence of internalized and socially imposed values and normative frameworks.

Cognitive systems (strategies)

Cognitive systems are related to the mental frames through which actors give meaning to social reality. While the normative perspective sees institutional compliance as a product of social obligation, cognitive systems function according to cultural legitimacy. Individuals and organizations have socially mediated constructions of common frameworks of meaning.

These frameworks exist at different levels: they could be a shared definition of local situation, patterns of beliefs which compromise the culture of an organization, or they are shared assumptions and ideologies that determine preferred political and economic systems (Scott, 2013). They are guidelines for choosing meaningful actions. Social identities are very important in this respect: they provide conceptions of what ways of actions make sense, and what individuals *want to* comply to. One important mechanism that maintains wide beliefs systems is imitation. Individuals and organizations seek to behave in conventional ways according to the shared logics of action, and mental models which exist. Mimetic processes help to internalize them (Scott, 2013). Other types of behaviour are not conceivable, and cognition therefore has an important constitutive function. It helps to define the nature and properties of actors and their actions.

Table 2: characteristics of different types of institutions (based on Scott, 1995, p. 35; Watkins & Westphal, 2016, p. 103).

Characteristic	**Type of institution**		
	Cognitive	**Normative**	**Regulative**
Carriers of institutions	*Cultures* Category, typology *Social structures* Structural isomorphism, identity *Routines* Performance programmes, scripts	*Cultures* Values, norms *Social structures* Regimes, authority systems *Routines* Roles' conformity, performance of duty	*Cultures* Formal rules, laws *Social structures* Power systems *Routines* Protocols, standard procedures
Basis of compliance	Taken for granted ('want to')	Social obligation ('ought to')	Expedience ('have to')
Mechanisms	Mimetic	Normative	Coercive
Logic	Orthodoxy	Appropriateness	Instrumentality
Indicators	Prevalence, isomorphism	Certification, accreditation	Rules, laws
Sanctions	Automatic (e.g. change in efficiency, productivity)	Emotional (e.g. guilt, pride, joy, anger…)	Tangible (e.g. fines, rewards)
Basis of legitimacy	Culturally supported, conceptually correct	Morally governed	Legally sanctioned

2.2.2 Formalizing the types of institutions: the Grammar of Institutions

The typology of institutions from Scott (1995) gives a overview of different types of institutions, or influencing forces on actors. One important tool for formalizing these institutions is the grammar of institutions, also known as the ADICO syntax, for observing different types of institutions (Crawford & Ostrom, 1995). The syntax rests on the finding that each institutional structure (rules, norms, and strategies) rests on a different ground for explaining observed regularities in behavioural patterns. Strategies focus on the internalized social frames which explain regularities in patterns of behaviour. Norms are the prescriptions which regulate behaviour. Rules regulate behaviour through their coercive nature. In each case, institutions articulate constraints and opportunities for social behaviour, and these articulations can be expressed as so called *institutional statements*. An institutional statement is a "shared linguistic constraint or opportunity that prescribes, permits, or advices actions or outcomes for actors…they are spoken, written, or tacitly understood in form intelligible to actors in an empirical setting" (Crawford & Ostrom, 1995, p. 583).

Table 3: the ABDICO syntax (based on Crawford & Ostrom, 1995, p. 584; Siddiki et al., 2011).

Components of institutions			Type of institution		
Letter	Component	Meaning	Strategy	Norm	Rule
A	**A**ttribute	The actor whom an institutional statement applies to.	x	x	x
B	O**b**ject	The inanimate or animate part of a statement that receives the action.	x	x	x
D	**D**eontic	The prescriptive operator that indicates whether the attribute is required, forbidden, or permitted to carry out the action of the statement.		x	x
I	A**i**m	The action of the statement.	x	x	x
C	**C**ondition	The temporal, spatial, or procedural boundaries in which the action of the statement is or is not to be performed.	x	x	x
O	**O**r else	Incentives for performing the focal action.			x

Institutional statements allow one to standardize and observe institutions through their linguistic commonalities and differences (Basurto et al., 2010). Institutional statements are operationalised according to Table 3. Siddiki et al. (2011) added an additional component to the original ADICO syntax, and used the term *ABDICO* syntax instead. With this syntax, the elements that all types of institutional statements have in common can be identified, as well as the elements that are unique to certain types only. It does not matter whether an institution is written in policy documents, spoken, or tacitly understood, either way an institution can be rewritten as an institutional statement with the ABDICO syntax (Crawford & Ostrom, 1995, p. 584; McGinnis, 2010).

Attributes determine the subset of a group to which an institutional statement applies (Crawford & Ostrom, 1995, p. 584). Depending on the description of the attributes, the subject addressed by the institutional statement can range from an individual, to a subset or all the participants of a group (Schlüter & Theesfeld, 2010). On an individual level, attributes may be values of variables such as age, residence or position. Examples of organisational variables are for instance the location, or the total number of members (Crawford & Ostrom, 1995). When no specific attribute is listed, the institutional statement applies to all members of a group.

By using a *deontic*, it becomes clear whether an institutional statement is prescriptive or non-prescriptive. A deontic expresses what is permitted, obliged, or forbidden (Crawford & Ostrom, 1995, p. 584). In the institutional statements, the words *may*, *must*, *should*, *must not*, and *should not* are often used. As one can see, these words differ in their prescriptive force (Basurto et al., 2010). *Must* can be linked to something which is forbidden, and is more likely to be part of a rule rather than a norm. S*hould* on the other hand is more likely to be associated with a norm. However, other operators can be used as well. For example, *required* suggest that the attribute *must* carry out the action (Siddiki et al., 2011). Strategy statements do not have a deontic, because the statement is not created or imposed upon an actor. Rather, it follows automatically from an action, for example: "the person who places a phone call, calls back when the call gets disconnected" (Ghorbani, Aldewereld, Dignum, Noriega, 2012, p. 74). Using a deontic therefore constitutes actions, either permits or restricts different participants in carrying out the action, and thus constrains participants in their behaviour.

An *aim* describes outcomes or actions to which the deontic refers. It tells what to do according to the institutional statement (Crawford & Ostrom, 1995, p. 584).

Conditions express the qualifiers of the aim. They include *when* (e.g. temporal or in relation to a process), *where* (e.g. geographical or jurisdictional), and *how* (e.g. through a defined process) an institutional statement applies. It thus expresses when the *attribute* is triggered to carry out the *aim* of the institutional statement. If a condition is not particularly stated, it means that at all times and at all places the institutional statement applies (Crawford & Ostrom, 1995).

Or else components differentiate norms from rules. They express explicit sanctions in case of non-compliance of the *attribute* to the institutional statement. Only rules have this component. For threats to be classified as rules, three conditions apply. First, there must be rules or norms which back up monitoring of compliance. Second, the constraints and opportunities that actors face when monitoring conformance must be expressed in institutional statements. Third, these institutional statements related to the monitoring need to be agreed upon in a collective action process (Schlüter & Theesfeld, 2010).

Siddiki et al. (2011) added a sixth component to the grammar called the object. The object is defined as the inanimate or animate part of a statement that receives the action. The action is the aim, and is carried out by the attribute (Siddiki et al., 2011, p. 9). The object is useful in cases when multiple attributes are named or when the attribute is not explicitly stated. The object helps to reduces coding ambiguity and helps the analyst in clearly differentiating all the components in a statement.

2.2.3 Formalizing the system of institutions: the Institutional Analysis and Development (IAD) framework

Ostrom sees institutions as the "shared concepts used by humans in repetitive situations organised by rules, norms, and strategies" (Basurto et al., 2010, p. 523). According to Ostrom (2011), rules, norms, and strategies are created and changed through human interactions in frequently occurring or repetitive situations. In order to depict the environment in which institutions apply, Ostrom (1990) created the Institutional Analysis and Development (IAD) framework (Figure 3). The IAD framework defines the major structural elements and their general relationships that are necessary to understand how the interactions between actors are shaped from an institutional perspective.

An important conceptual unit in the framework is the action arena. An action arena consists of action situations and actors. Actors can be single individuals, or a group which functions as a corporate actor. The actors interact with each other in the action situation. There, they might exchange goods or services, work towards problem-solving, dominate each other, or fight (among the many things that individuals do in action arenas) (Ostrom, Cox & Schlager, 2014, p. 271). In this respect, the IAD framework considers actors to be "fallible learners", who operate under uncertainty, with limited cognitive and information-processing capability, but who are able to learn from the past interactions over time (McGinnis, 2011, p. 171).

The action arena is influenced by three sets of external variables: the attributes of the physical world, the attributes of the community, and the rules-in-use. Attributes of the physical world include physical and material conditions affecting the action arena (Lam, Lee & Ostrom, 1997). Examples are biophysical resources, capital, labour, technology, finance, and distribution channels. Important attributes of these resources are for instance their size, abundance, and their vulnerability (Clement, 2010). Attributes of the community are more cultural. These cultural aspects relate to the generally accepted norms by a community, the level of common understanding and trust, and the extent to which values, beliefs, and preferences among community members are homogeneous (Polski & Ostrom, 1999, p. 19-22).

Rules-in-use is a term which refers to formal dictums, as well as more informal norms of behaviour (Bollman & Hardy, 2016). At times, formal and informal institutions may contradict each other. Therefore, the rules-*in-use* refer to the institutions which are *actually followed in practice* by actors.

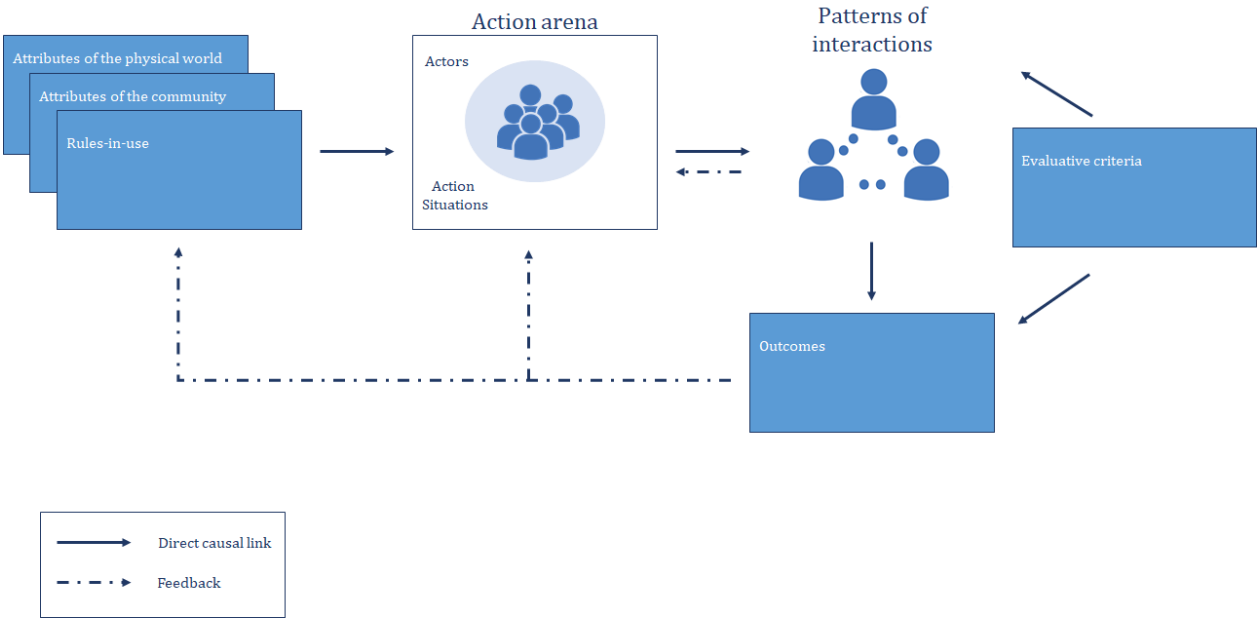


Figure 3: the Institutional Analysis and Development (IAD) Framework (based on Ostrom, 2011, p. 10).

The action situation is therefore a social space, used to explain the regularities in actor behaviour (Polski & Ostrom, 1999). It can be used for the prediction of likely outcomes, by understanding what elements affect the structure of an action situation. From the structure of the action arena, a pattern of interactions will result into outcomes. For the outcomes and the processes of achieving the outcomes, criteria will be applied to evaluate if the desired outcomes are achieved under the existing institutional arrangements (Figure 3). Through evaluative criteria, feedback processes occur to the attributes of the world, community attributes, and rules-in-use. This is how institutional change occurs. The action arena itself is also affected, because the actors involved might have changed as well in their strategies or objectives for example. This all depends on the criteria under consideration. These criteria may be related to economic efficiency, fiscal equivalence, distributional equity, accountability, morality, or sustainability (Ostrom, 2007).

To better understand how institutions influence the actions and outcomes undertaken by the participating actors, they can be further characterised in three ways. In the first place, institutions (e.g. rules, norms, and strategies) can be characterised as rules, norms, or strategies, by considering their *grammatical components* using the ABDICO syntax (Table 3). In the second place, one can look at the *level* at which institutions operate. In the third place, one can study the specific *function* of an institution in the action arena (Watkins & Westphal, 2016).

The level of institutions

According to Ostrom (1999), institutions exist on an operational, collective-choice, and constitutional level (Figure 4). There is even a meta-constitutional level, that is not frequently analysed (Ostrom & Ostrom, 2014). On an operational level, institutional statements directly influence day-to-day management, enforcement, appropriation, and provision actions. The operational statements relate to practical decisions made by actors that have been authorized (or allowed) to take these actions due to processes on a collective-choice level (McGinnis, 2011; Bisaro et al., 2018). In the context of climate adaptation, the operational statements may relate to how risk levels of infrastructures are assessed for example. On a collective-choice level, statements determine who is eligible to change operational institutions and in what manner this can be done (Watkins & Westphal, 2016). The institutions on this level concern the prescription, monitoring, appliance, and enforcement of the statements structuring activities on an operational level (Clement, 2010, p. 7). On a constitutional level, institutions determine the eligibility of participants to make and change the collective-choice institutions. In essence, the decision-making and institutional statements on a constitutional level affect the collective choice-level, which in turn affects the operational level. The lower levels can in turn, exert an influence over the upper levels (Figure 4).

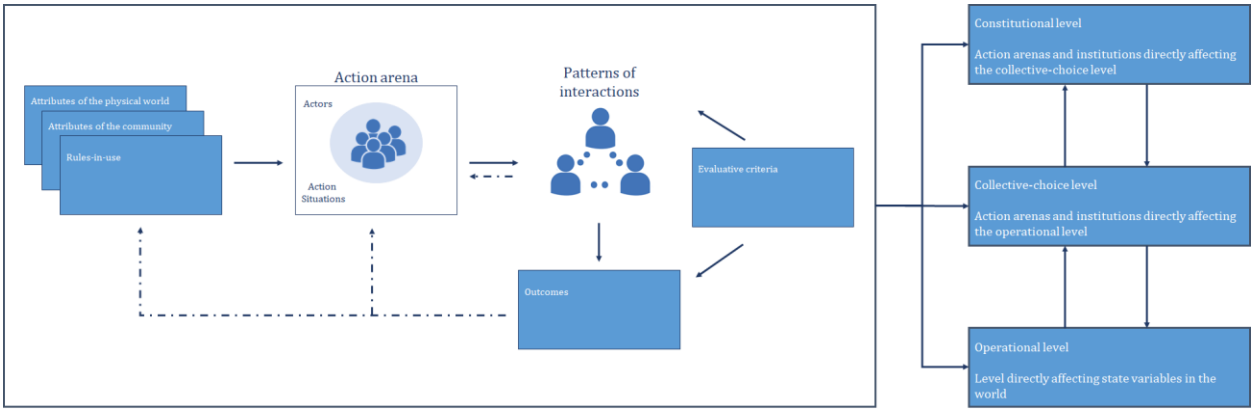


Figure 4: the link between the level of institutions and the components within the IAD framework (based on Polski & Ostrom, 1999, p. 28; McGinnis, 2011, p. 173).

Seven functions of institutions

There are seven functions that an institution may have, depending on which component in the action situation it impacts (Figure 5). In the action situation, you have positions to which actors and actions are assigned. Positions are essentially classes of actors. Each class has actors as its own participants. An example is an association, where each member has a role. The actions are behaviours of acting to which actors, or the classes of actors, attribute a valuation to, depending on the instrumental use they see in an action. Actors, positions, and actions, are respectively influenced by boundary statements, position statements, and choice statements. Boundary statements define whether and under what circumstances an actor can join the action situation. This also includes their attributes and resources, and possible consequences when leaving. A boundary statement determines eligibility for a position and therefore is closely related to position statements. Position statements essentially appropriate the different classes of actors to the actions in the action situation (Ostrom, 2011). Choice statements explain which choices actors have related to the actions they can take, such as approval which needs to be given. In taking action, there are information and aggregation rules which respectively look at information types and flows, and joint control over action. Control implies that given the position that an actor is assigned to, he has more or less influence in the selection of an action.

Aggregation statements determine the joint control over an action, such as the number of participants who need to decide over an issue, or the process of several persons who are required for approval (Watkins & Westphal, 2016). Information relates to the knowledge-sets of participant classes. The information statements impact the types or level of information that the participants have. Examples of information statements are statements that determine whether information is held public or private, and to whom information is shared. Depending on the actions that actors take, different outcomes could potentially result from an action situation. Scope statements in this respect delimit the potential number of outcomes and link the outcomes under consideration to the actions that actors can take (Ostrom, 2011). Actions and outcomes have costs and benefits, which can incentivise or deter actors from undertaking actions. Payoff statements affect the benefits (a raise, or reward) and costs (a fine or getting fired) assigned to actions and outcomes.

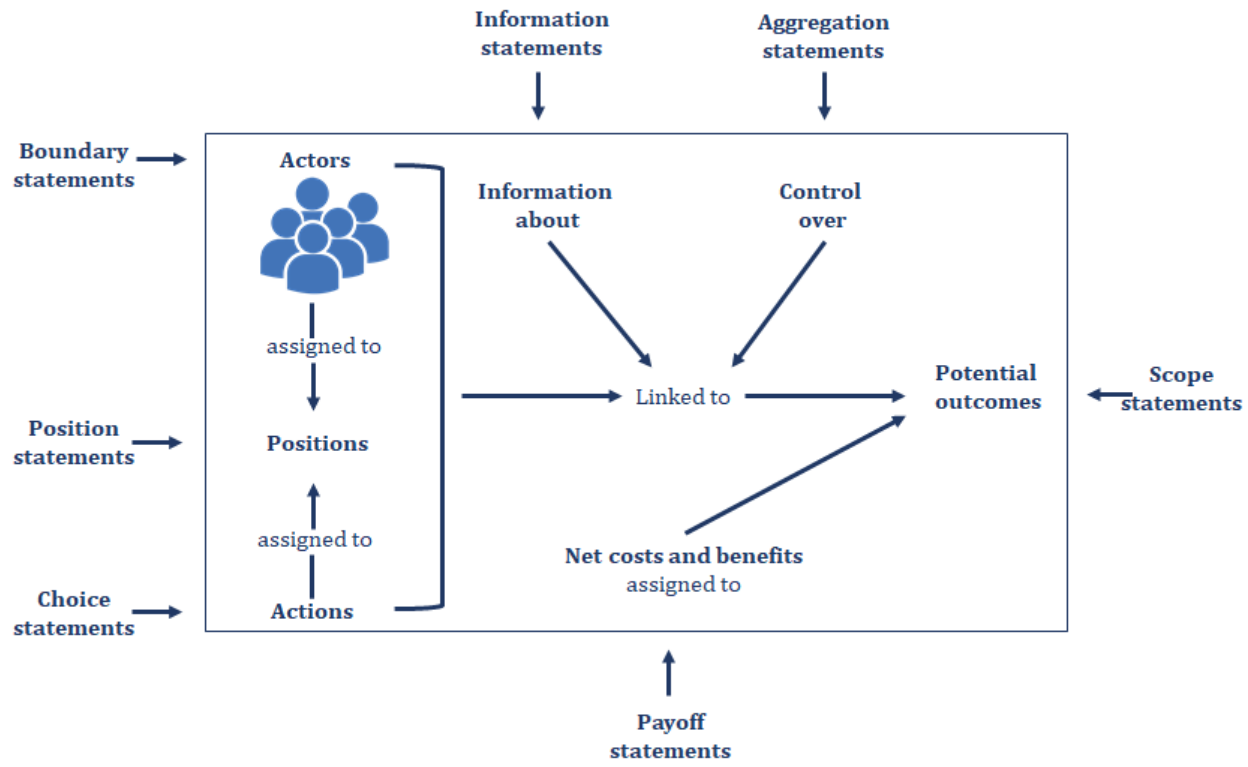


Figure 5: the structure of an action situation together with the classification of statements (based on Ostrom, 2011, p. 20).

By combining all three dimensions along which institutions can be characterised, it is possible to understand the actions of individual actors, and the aggregation of individual actions into outcomes for the whole community (Figure 6). An actor will choose actions which are deemed to be suitable in the decision-situation. The decision-situation exists through the biophysical attributes, community attributes and the rules-in-use, the given institutional arrangements. As these arrangements change, individual actors will also make different choices. Actions of all the actors involved aggregate into results and outcomes, with their feedback effects to the actors themselves and the existing institutional arrangements (Kiser & Ostrom, 2000).

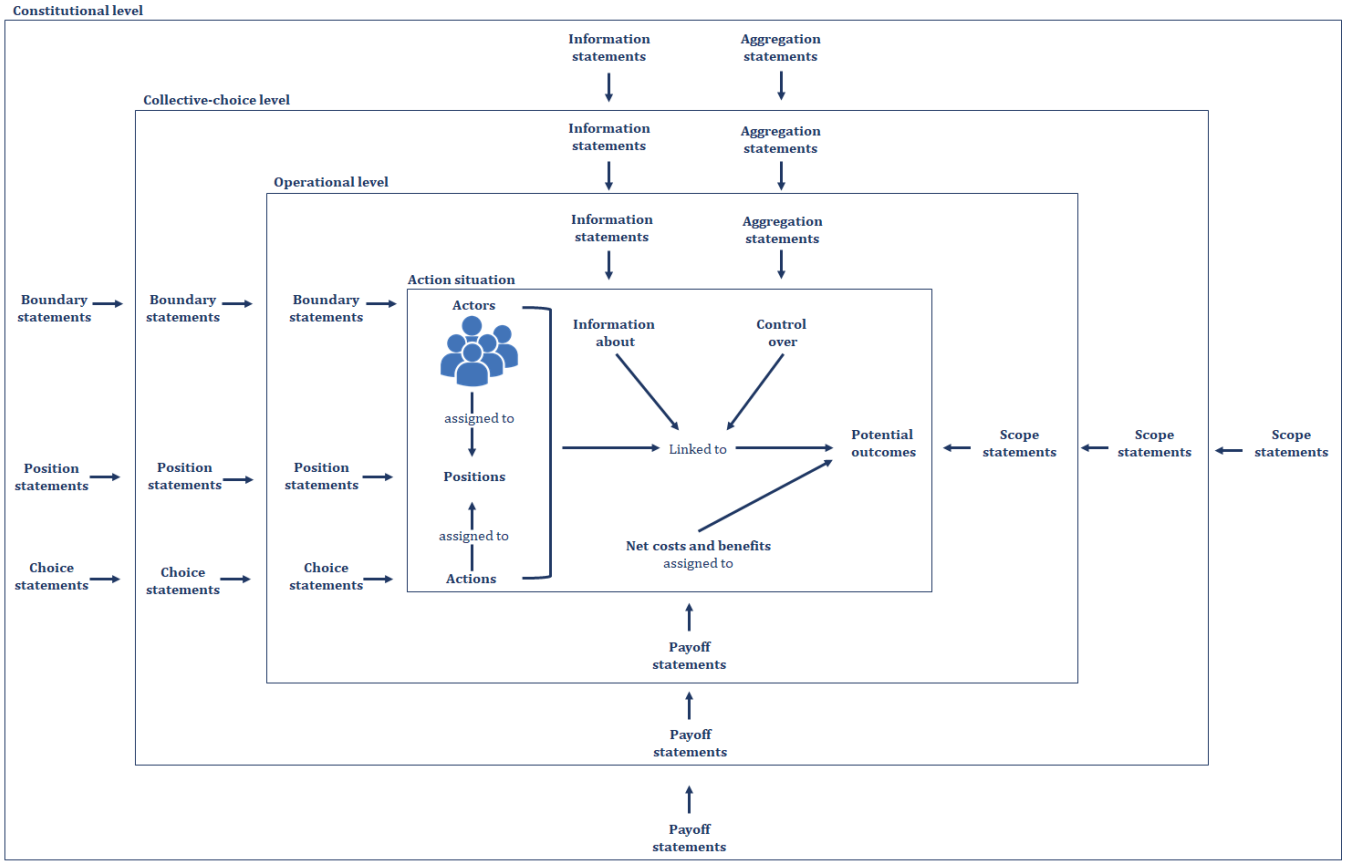


Figure 6: the three dimensions along which institutions can be characterised – their grammatical components, their level of operation and their function (based on Ostrom, 2011).

2.3 Understanding relations between institutions

In this section, I provide a brief overview of how institutions have been studied in the context of climate adaptation. Then I shift the focus to the network paradigm for connecting institutions.

Institutions are created, reinforced, or reproduced to influence, and steer, if not completely control, the behaviour of actors for the realization of collective goals (Hufty, 2011; Termeer et al., 2011). In the context of climate adaptation, the use of institutions ultimately aims at addressing the impacts of episodic and extreme events such as extreme precipitation, droughts, and floods on transport infrastructures (Earl & Potts, 2011). Existing studies usually distinguish between formal and informal institutions, rather than between rules, norms, and strategies. Formal institutions are explicitly set by legislators and may manifest through laws, regulations, and protocols. Informal institution are more implicit, like administrative practices, norms, professional codes, traditions, and customs (Juhola & Westerhof, 2011; Obeng & Agyenim, 2013).

The focus in literature on the institutional dimension of climate adaptation is two-fold. One body focusses on whether existing institutions allow and encourage actors to develop and realize adaptation strategies to enhance the adaptive capacity of society (Termeer, Biesbroek & Van den Brink, 2011). Adaptive capacity is developed when institutions allow actors to effectively prepare for climate stresses and changes and to adjust, respond, and adapt to them (Berman, Quinn & Paavola, 2012; Obeng & Agyenim, 2013).

The idea is that institutions must enable policy learning, and the changing of trajectories and adaptation practices when required. These characteristics fall under so-called adaptive governance (Termeer et al., 2011). An example is when institutions stimulate organisations' capacities to collect and manage data about climatic events and their impacts (Diaz & Hulbert, 2013). Based on new findings, current measures can be adjusted or their implementation can be preponed or postponed. Another example are safety norms which are adapted based on the expected future climatic impacts.

The other body of literature focusses on the institutional void. Institutional void refers to the lack of formal planning and management tools due to a lack of laws and other formal institutions on climate adaptation (Biesbroek, Termeer, Kabat & Klosterman, 2009). In other words, there are no generally accepted institutions according to which policy measures are to be agreed upon (Hajer, 2003). A consequence of this is that parties engaging in adaptation efforts have very diverse, and at times, conflicting risk perceptions in mind (Preston, Rickards, Fünfgeld & Keenan, 2015).

In both bodies of literature, institutions are mostly studied in isolation from each other to see if they stimulate the adaptive capacity in their own policy-making context (Stead, 2013). When 'institutional interactions' are mentioned, the focus is on the interactions between organisations at different institutional levels rather than the interactions between the institutions (Glaas & Juhola, 2013). The interactions between two or more distinctive institutions (here, the organisations) that interact in their governance of the same activity is what is referred to as 'institutional complexity' (Oberthür & Stokke, 2012, p. 3). In climate adaptation, this complexity manifests due to a growing number of actors, with diverse normative views, and who are interdependent for the realisation of policies (Bruin et al., 2009). Here, 'institutional complexity' does not relate to the connections and interdependencies between institutions that govern the interactions of these actors.

However, this does not mean that the interrelations between institutions are not acknowledged at all. Researchers have expressed concerns over tensions or barriers in policy-making which result from the dependencies between institutions. Oberlack (2016) mentions that formal rules on a higher institutional level might constrain the changing of lower-level rules, thereby constraining the extent to which local actors can undertake adaptation efforts. The effectivity of institutions for adaptation measures therefore also depends on other institutions and whether they foster policy learning necessary to improve adaptation measures in place (Juhola & Westerhof, 2013). In such a context, and in this research, institutional complexity relates to these interdependencies and the connectivity between institutions.

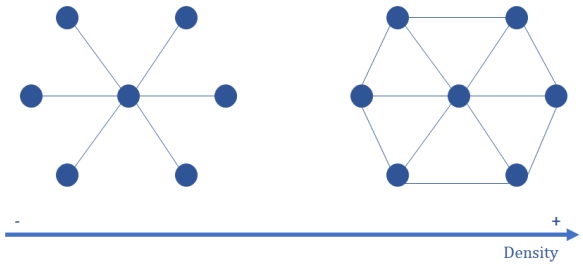
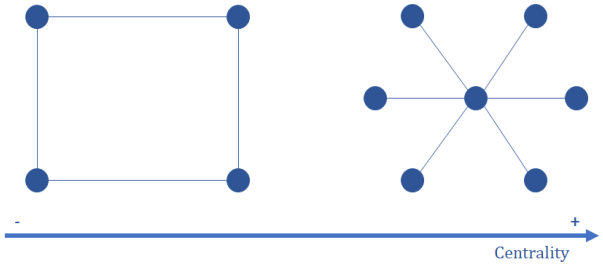
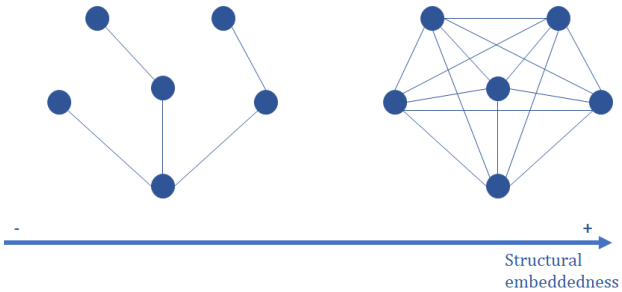
With respect to the relations between institutions, the notion of institutional conflict has also been mentioned in existing studies. The first set of definitions refers to institutional conflict as a conflict in the divergent objectives, or interests (Oberthür, 2009). Here, the focus in an institutional conflict is again on the organisations who are involved rather than the institutions that guide them. The second type of definitions focusses more on the connections between institutions (Biesbroek et al., 2009). Institutional conflict occurs when institutions at different levels of governance vary from each other, and lead to the adoption of *conflicting institutional structures* by actors involved in climate adaptation. This means that there are multiple institutions in place which are guiding actor behaviour, and that each of these institutions lead to different outcomes. Here, institutional hierarchy comes in play since in practice, actors may choose and give prevalence to one of the institutions over the others. Therefore, an institutional conflict in this research is defined as two or more institutions with different outcomes guiding actors.

Social network paradigm and the institutions for climate adaptation

So far, the focus in existing studies is on the individual organisations governed through institutions rather than the institutions which influence their behaviour (Bruin et al., 2009; Glaas & Juhola, 2013). While dependencies between institutions have been acknowledged in existing literature (Oberlack, 2016), the relations between institutions are not systematically identified or studied at the level of institutional statements.

The social network paradigm helps to shift the focus away from the individual organisations to the relations that exist between them. A social network consists of a set of nodes (actors) and ties (relationships). Together, the ties connect the nodes and thus shape social structures from which different insights can be generated though social network analysis (Schnegg, 2018). Social network analysis (SNA) is a quantitative method which helps to visualise, and statistically and graphically investigate the patterns of interactions or connections between the individual nodes.

Table 4: three network metrics in SNA (adapted from Daub, 2009; Karali et al., 2020; Kinnear et al., 2013)

Network metrics	
Density	
Density is calculated based on the proportion of the total number of actual interactions among the actors in a network, out of the total number of potential interactions. The higher the value, the higher the connectivity.	
Centrality	
Centrality is an indication of the ability of an actor in the network to communicate with others. Degree centrality measures how many ties a node possesses, while betweenness centrality measures how often a node lies between two other nodes.	
Structural embeddedness	
Structural embeddedness provides information on the network involvement of actors, and their positional power. A high individual embeddedness implies that information can be easily circulated in the network, but also the presence of institutional redundancy.	

Due to the focus on the ties between entities in a defined network, one can calculate social network metrics (Jaja, Dawson & Gaudet, 2017). These network metrics generate information on the structure of the network, its functioning, but also the strength of relationships between individual entities, and the roles of individual entities in a network (Karali, Bojovic, Michalek, Giupponi & Schwarze, 2020). Researchers have distinguished several network metrics (Table 4) for the study of actor networks involved in climate adaptation (Karali et al., 2020; Kinnear, Patison, Mann, Malone & Ross, 2013).

The density of a network provides information on the number of reported ties between all nodes relative to the number of possible ties. A high density indicates that many nodes, or actors, collaborate with each other and exchange information. A low density on the other hand indicates few connections between the actors involved. While few connections between the actors indicate little sharing of information throughout the entire network, it can also bring about diversity in practices. This can be practical when diversity in climate change responses is needed (Janssen et al., 2006).

Centrality measures describe the importance of actors in networks based on their ties with others. Degree centrality measures the number of ties it has in a network, and indicates popularity, or influence in a network. While high centrality brings efficiency in the coordination between the nodes, it also has a risk for the whole network since removal of the node makes the network very vulnerable (Janssen et al., 2006).

Apart from density and centrality, embeddedness is an important network characteristic because it focusses on the positional power of actors based on their relations in the network (Vernet, Kilduff & Salter, 2014). In this research, the focus will be on structural embeddedness, which is the "structure of relationships around actors" (Gulati & Gargiulo, 1999). Low embeddedness of an individual implies that the circulation of information is more difficult, and also implies less social constraint on individuals which may lead to corruption. High embeddedness of an individual allows for easy spread of information, but also more social control and institutional redundancy (Vernet et al., 2014).

While SNA allows one to understand the connections between actors in a structured way through a network, it does not shed much light on *why* actors have certain roles in the network or what institutions exactly relate actors to each other as shown in a network.

Another tool that draws from the social network paradigm as well and shows the formal relations between actors based on important laws, legislation, procedures, and authorities that play a role in a problem situation is the formal chart (Enserink et al., 2010, p. 90). An example of a formal chart is shown in Figure 7. The single-sided arrows between actors indicating a hierarchical relationship, while the two-sided arrows indicate a formal representation relationships/memberships (Enserink et al., 2010, p. 91). While the formal chart does show which laws and procedures actors deal with and influence interactions between actors, not all the links in the formal chart are explicitly defined. Furthermore, while the laws and procedures are bundles of institutions, the chart does not show what decision-making space they apply to, and how actors exactly act given the influence of these institutions.

This is why in this research, the links between the actors will be defined through institutional statements that are applicable in different action arenas. This helps to gain a better understanding of both formal and more informal institutions that govern actors in their decision-making. The focus on the nature of the ties between actors, the institutional complexity and its impact on the network performance are better understood.

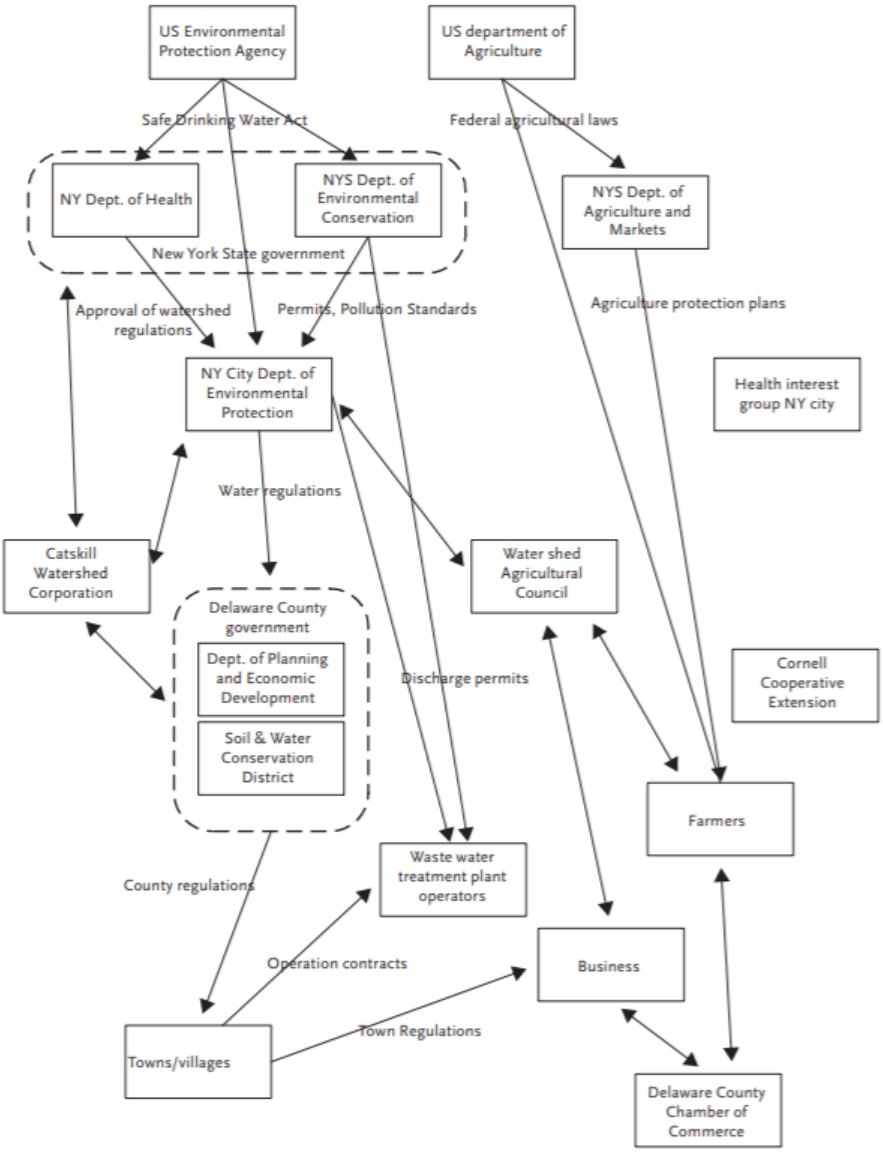


Figure 7: example of a formal chart (Enserink et al., 2010, p. 91).

2.4 Framework for analysis

The institutional analysis of climate adaptation has so far looked at the institutions in isolation from each other. The findings were that institutions either do not enhance the adaptive capacity, or that there is a lack of formal laws and other institutions on climate adaptation. When the notion of institutional complexity was introduced, the focus was not on the institutions themselves, but rather on the actors that they guide. While it was acknowledged that institutions can influence each other, their relations have not been systematically mapped on the level of institutional statements. The goal of this research is to map the interdependencies between institutions in order to understand what implications they have for climate adaptation policy-making and practices. These connections between institutions will be mapped according to a network-perspective. Network theory helps to put the focus on the relations between institutions, and therefore help to understand how interactions are shaped in the context of climate adaptation.

The IAD framework allows for the analysis of institutions by considering an action arena where interactions take place. The different components of the action arena are influenced by institutions, which can be studied along three dimensions (Figure 6):

1. The *grammatical components*, according to which institutional statements can be written (subsection 2.2.2). In this research, three kinds of institutions are distinguished: rules, norms, and strategies.
2. The *level* of an institution, which can be operational, collective-choice, or constitutional (subsection 2.2.3).
3. The *function* of an institution, which can influence different components within an action arena: position, boundary, choice, payoff, scope, aggregation, and information statement (subsection 2.2.3).

For climate adaptation in the Netherlands, there are seven ambitions or phases for spatial adaptation (section 2.1.2). This study will focus on the first three phases of the Delta Programme for Spatial Adaptation, namely: mapping out vulnerabilities, conducting risk dialogue, and drawing up an implementation agenda. The focus will be on the transport infrastructures connected to the Port of Rotterdam. In order to grasp the connections and interdependencies between the institutions for each phase, the interactions will be studied from a network-perspective, where actors are connected through the respective institutional statements.

The conceptual framework is shown in Figure 8. It shows how within the institutional dimension climate adaptation of transport infrastructures, the institutional complexity is the focus of this research.

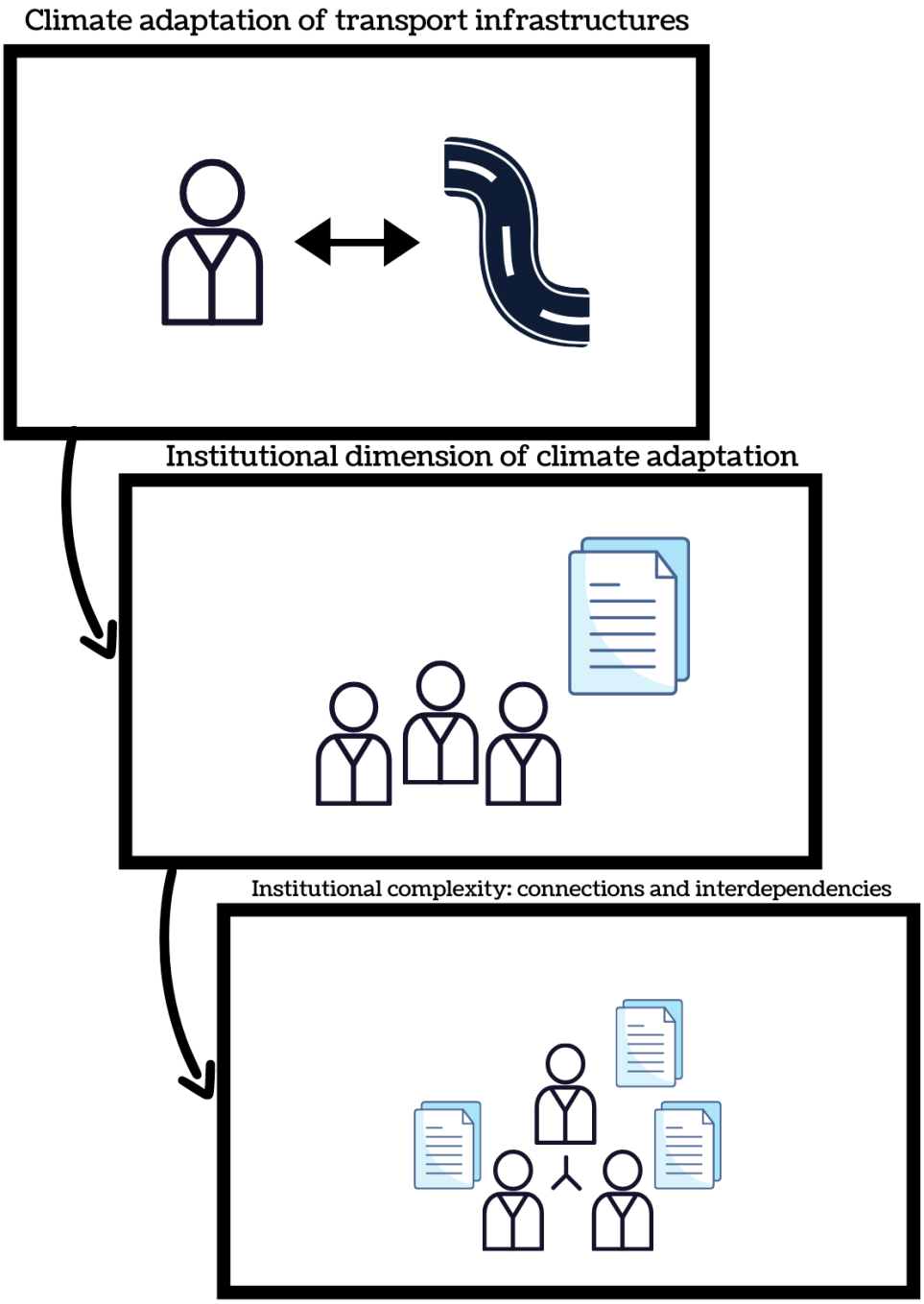


Figure 8: the graphical representation of the conceptual framework for this research.

3. Research method: Institutional Network Analysis (INA)

This chapter explains the steps for conducting the Institutional Network Analysis (INA) method (Figure 9). I used the conceptual framework from Chapter 2 to improve the prototype of this method, which was originally proposed by Ghorbani, Bosch & Siddiki (2020). Each section in this chapter explains how the steps were conducted, and which improvements had been made to the prototype of the INA method. Section 3.1 explains how the data is collected. Section 3.2 discusses the data coding and coding process. Section 3.3 shows the process for formalizing institutions according to the ABDICO syntax. The Institutional Network Diagrams (INDs) connect the formalized institutional statements according to a network structure, as explained in section 0. The steps for the analysis of the INDs are given in section 3.5. In section 0, it is explained how the INA method was validated, and how the results of the analyses were communicated to the respondents.

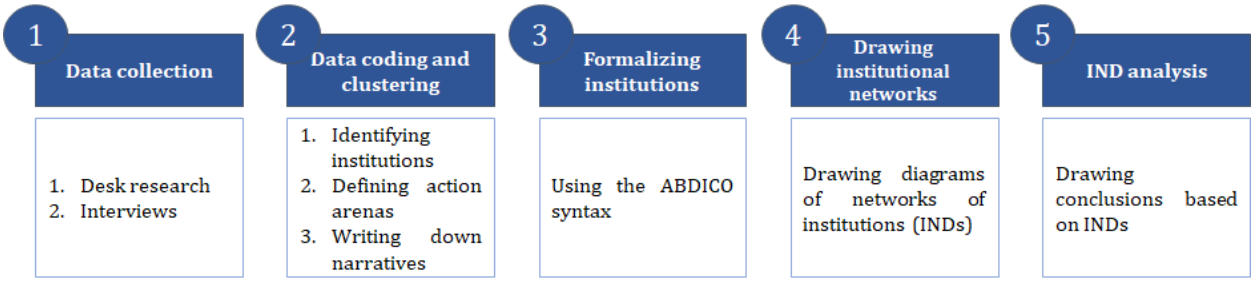


Figure 9: the steps of the Institutional Network Analysis (INA) method (adapted from Ghorbani et al., 2020).

3.1 Step 1: Data collection

In the first place, it was necessary to gain a better understanding of the climate adaptation activities undertaken for infrastructures connecting the Port of Rotterdam to the hinterland. This was done through desk research and semi-structured interviews. Desk research provides insights on existing institutions through publicly available resources such as official government documents, laws, and regulations. Table 5 gives a list of key documents which were reviewed during the desk research. The full overview of sources is shown in Appendix A.

However, since climate adaptation is a new field in climate policy, semi-structured stakeholder interviews will be crucial to learn about implicit institutions, such as norms, and shared institutions. Unlike structured interviews, semi-structured interviews do not have to be guided by a rigorous set of questions, but may be guided by a list of topics for instance, allowing for the outcome of the interview to be open (Ghorbani et al., 2020). The list of topics with some example questions is shown in

Table *6*. These topics and examples questions are a summary of the full list of interview questions in Appendix B. The example questions were formulated by using the seven functions of institutions (subsection 2.2.3). This was done to ensure that questions did not relate to one function of institutions only. Since the interviews were semi-structured, the full list was not meant to rigorously guide the interview per se, but was used when it was useful during the interviews. In this way, it was

possible to deviate from the pre-defined topics and interview questions and focus on new aspects brought forward during the interviews.
The list of actors who were interviewed is shown in Table 7. The selection of respondents was based on five criteria which guided the selection of organisations and the individual respondents.

1. *The respondent is part of an organisation which owns and manages transport infrastructures connected to the Port of Rotterdam*. The Port of Rotterdam has an extensive network of intermodal transport connections, namely: rail transport, inland shipping, road transport, and pipelines. In the first place, it was important to approach actors who own and manage these infrastructures. The rail infrastructure is owned by ProRail. Inland waterways and roads are either owned by Rijkswaterstaat or the Province of South-Holland. Pipeline owners are mostly chemical companies and refineries. Pipelines run between companies in the port, or run to other destinations in the Netherlands, Belgium, and Germany. One of the supervisory bodies for the pipelines routes in LSNed.

2. *The respondent is part of an organisation who is a user of the ports' infrastructure*. The logistic, ports, and industrial enterprises in the Port of Rotterdam are represented by the interest group Deltalinqs. Disruptions in infrastructures connected to the port pose economic risks to these users. Therefore, it was also important to understand to what extent and in what way the private sector was involved in climate adaptation.

3. *The respondent is part of an organisation who has a stake in climate adaptation in the Port of Rotterdam*. The Municipality of Rotterdam is the biggest shareholder in the port. It does not only attach value to the economic prosperity of the port, but also to the societal disruptions which might result from problems that the users of the infrastructures experience. Therefore, its involvement is crucial to implementing climate adaptation policies.

4. *The respondent is affiliated with climate adaptation policy-making in the Netherlands*. There were several organisations who were approached with this criterion in mind. First of all, the Ministry of Infrastructure and Water Management is the responsible ministry for climate adaptation in the Netherlands. An interview with this Ministry helps in getting a better understanding of the larger and more long-term objectives behind the current structure of Delta Plan for Spatial Adaptation. Furthermore, the Royal Dutch Meteorological Institute was approached since this institute is responsible for making scenarios for climate change in the Netherlands. The institute may therefore provide information on how this data is used and what the needs are of different actors in terms of climatic information.

5. *The respondent was involved in climate adaptation efforts in or surrounding the Port of Rotterdam.*

Table 5: a list of key documents reviewed during the desk research.

Documents	
Adaptation phase	**Sources**
Mapping out vulnerabilities	Standardised stress test information leaflet for the Delta Plan for Spatial Adaptation, other climate impact research of infrastructure owners.
Conducting risk dialogues	Risk dialogue guides, climate adaptation strategies (national, regional, local).
Drawing up an implementation agenda	Climate adaptation implementation programmes, climate adaptation guides (e.g. how to preserve climate-resistance in planning), rules and guidelines for infrastructure construction.

Table 6: the topics based on which the semi-structured interviews were conducted with some general example questions.

Questions	
Topics	**Example questions**
Knowledge gathering efforts	In what ways do you assess the sensitivity of an area for climate impacts? Are stress tests the leading means for knowledge improvement? Do you work together with other parties in knowledge gathering efforts (e.g. providing input, collaborative research…)? How often do you update existing research?
Risk assessment and perception	What climatic impacts do you focus on the most? How do you decide whether a climatic impact is significant?
Knowledge exchange	How are risks communicated between actors? Through risk dialogues? Which parties participate in these dialogues? What are the objectives of these dialogues? How do you decide which knowledge base to give prevalence to, given that different parties conduct research? How do you come to an agreement on the course of action to take?
Implementation and monitoring	Which rules and regulations do you have to comply to in spatial adaptation of infrastructures? When is a policy climate-resistant? How do you translate your knowledge efforts into climate adaptation measures? How do you decide which measures are necessary? Who is responsible when climatic hazards impact infrastructures?

Table 7: list of actors who were interviewed.

Actors	
Government agencies	Ministry of Infrastructure and Water Management, RWS, (**R**ijks**w**ater**s**taat, the executive agency Ministry of Infrastructure and Water Management), Province of South-Holland, Municipality of Rotterdam.
Experts	Dutch Royal Meteorological Institute (KNMI)
Private sector	LSNed, ProRail, Port of Rotterdam, Deltalinqs

Given the five criteria for stakeholder selection, respondents within the different organisations were selected. Respondents with job positions which included the words "spatial adaptation", "environmental", or "climate adaptation" were the first to be contacted. The contact details of the respondents were obtained through consultants from Dutch consultancy firm AT Osborne who had worked with respondents during previous projects, or public websites of the relevant organisations online. Through email, the purpose of the research was explained, and timeslots were proposed for an interview. This allowed respondents to prepare for the interview in advance, or if needed, to redirect the researcher to other colleagues. A total of 29 potential respondents were contacted, of which 16 agreed to participate in an interview. While all the interviews were planned at the working offices of the respondents, the interviews were conducted online through Skype, Microsoft Teams, or phone calls because of the coronavirus outbreak. Prior to the interviews, prepared consent forms were emailed to the respondents, and emailed back. During all the interviews, notes were taken. The interviews were recorded, and transcripts were made for the data coding and clustering (step 2), and the formalization of the institutions (step 3).

3.2 Step 2: Data coding and clustering

After the transcripts were made, a first analysis was conducted through discourse analysis. Discourse analysis allows for the examination of argumentative structures to understand what narratives interviewees use when describing important themes related to climate adaptation (Hajer, 2006). By understanding the way that themes are linguistically represented, one learns more about the

perceptions of stakeholders, and whether commonalities exist among stakeholders' descriptions. Moreover, one learns whether certain positions are being criticized, or whether justifications are mounted against them (Hajer, 2002). Insights on the identity of an organisation also provides insight on the formal institutions that guide actors, and vice versa (Enserink et al., 2010).

The first step of the discourse analysis is to look at the research questions, and write down a few initial themes that one expects to find in the data. After formulating the initial themes, all the transcripts were read to write down the common themes that were found within the transcripts. These themes, along with the three phases of climate adaptation, were then used for *coding* the data. Coding is a method used to analyse data by identifying themes, or 'codes', that appear in the qualitative data, and then assigning sections of the data to these codes (Harding, 2015). When reading the transcripts carefully, one always comes across new themes, and in order to do justice to the richness of the text, these themes were also coded. After the initial coding was finished, the existing codes were reviewed. The overview of codes for each interview transcript can be found in Appendix C. The following larger clusters were identified:

1. *Important risks for infrastructures*. When explaining climate adaptation efforts, respondents had different climatic impacts that they considered to be critical for their organisation. This was done by giving examples of how the functionality and capacity of infrastructures is affected by these impacts, such as drought, extreme weather, or heavy rainfall.
2. *Rules and guidelines*. Respondents explained according to which frameworks their organisation were undertaking climate adaptation efforts.
3. *Measures which can be implemented for climate adaptation*. Given the geographic area or infrastructure that the organisation of the respondent owned and managed, different types of adaptation measures could be undertaken.
4. *Decision-making processes on climate adaptation*. Respondents described which decisions were undertaken for climate adaptation, and in what manner these decision-making processes took place (e.g. through iteration, one-off…).
5. *Links and cooperation between stakeholders*. Respondents mentioned different organisations cooperating with them in enhancing the knowledge on climate adaptation through research, or other actors they were dependent on for undertaking measures for infrastructures.
6. *Views and perceptions on climate adaptation efforts*. The stakeholders expressed how they perceive the cooperation and interaction with other stakeholders so far with respect to generating knowledge and forming an implementation agenda for climate adaptation. This includes different problems they mentioned in undertaking climate adaptation efforts.

Given the conceptual framework of this research (Figure 8), action arenas also need to be distinguished for the institutional analysis. For this research, three phases of climate adaptation are considered: mapping out vulnerabilities (knowledge gathering), conducting risk dialogue, and drawing up an implementation agenda. These three phases were therefore considered as the action arenas for this research as well, and the clustered data was again clustered under one of these three phases.

The coding and clustering was carried out in Atlas.ti. Atlas.ti is a workbench for the qualitative analysis of large bodies of textual, graphical, audio or video data. It guides the user in coding the materials so that patterns in their content can be found and analysed. For the analysis of the codes, the first thing which was done was to look at the language used within each theme. Insights regarding the relations between the transcripts in describing the themes were written down in memos in Atlas.ti. Then, for every respondent, a network was made with the network-creation function in Atlas.ti. This function allows the researcher to connect codes, along with their quotations in the

interviews. The relationships are defined by the researcher, and follow from reading the interview transcripts. Two examples of the networks are given in Appendix C.

3.3 Step 3: Formalizing institutions

After the data gathering, coding, and clustering was finished, institutional statements needed to be identified from both the sources from the desk research, as well as the interview transcripts. An institutional statement is a "shared linguistic constraint or opportunity that prescribes, permits, or advices actions or outcomes for actors…they are spoken, written, or tacitly understood in form intelligible to actors in an empirical setting" (Crawford & Ostrom, 1995, p. 583). For deriving the institutional statements from written sources (subsection 3.3.1), several (methodological) case study applications of the A(B)DICO syntax and the IAD framework were reviewed (Table 8). While the studies gave clear steps or guidelines for deriving institutional statements from written documents, there were no steps to guide researchers in doing the same with interview transcripts. Therefore, I propose a series of steps in subsection 3.3.2 to formalize institutions from interview transcripts with the *ABDICO* syntax. This contribution helps future users of the ABDICO syntax and INA method to better capture information from the interview transcripts in institutional statements.

Table 8: overview of methodological case study approaches to using the ADICO grammar of institutions and IAD framework.

Author	Research title	Description
Basurto et al. (2010)	A Systematic Approach to Institutional Analysis: Applying Crawford and Ostrom's Grammar	The researchers applied ADICO to two legislated policies in the United States.
Siddiki et al. (2011)	Dissecting policy designs: an application of the Institutional Grammar Tool	The researchers provide revised guidelines for applying the institutional grammar tool to four policies that shape Colorado State Aquaculture.
Watkins & Westphal (2016)	People don't talk in institutional statements: a methodological case study of the Institutional Analysis and Development Framework	The researchers applied the ADICO syntax to a study of ecological decision-making. They outlined their process for identifying institutional statements from documents and gave examples of statements from interview quotations.
Brady et al. (2018)	Institutional Analysis of Rules-In-Form Coding Guidelines	The researchers have outlined a series of coding methods that can be used to analyse institutions in policy documents – from administrative rules to constitutions.

3.3.1 Identifying institutional statements from documents

Identifying the components of institutional statements

The ABDICO syntax subdivides institutional statements into five different components:

1. **A**ttribute: the actor whom an institutional statement applies to. The process of identifying the attribute (A) is often times straightforward, for it is the organisation being interviewed or conducting the aim (I).
2. O**b**ject (B): the inanimate or animate part of a statement that receives the action.

3. **D**eontic: the prescriptive operator that indicates whether the attribute is required, forbidden, or permitted to perform the focal action of the statement. The deontic indicates the strength of enforcement of a statement. Words such as "should (not)" or "must (not)" both express the obligatory nature of a statement, however, "must" is more likely to be associated with a rule than with a norm, while "should" could be an indicator of both types of institutions.
4. A**i**m: the action of the statement. This is the "what" in an action, and present in all types of statements.
5. **C**ondition: the temporal, spatial, or procedural boundaries in which the action of the statement is or is not to be performed. Whenever specific conditions (C) are not mentioned by respondent, it is assumed that this implies that the statement applies at "all times and in all places".
6. **O**r else: explicit sanctions in case of non-compliance of the *attribute* to the institutional statement. A statement may have multiple sanctions or rewards embedded in it as well, which are gradually imposed over time or all at once.

As shown in Table 3, a rule contains all the components from the ABDICO grammar, unlike a norm and a strategy. This does not mean that strategies and norms have no sanctions, but that their types of sanctions are not necessarily captured in formally in legislation or documents. In the case of a norm, sanctions have an *emotional* nature, since going against the norm goes against the conception of what is the appropriate line of action. What makes the sanction of a strategy different from that of rules and norms is that the sanction is not created or imposed by another actor, but follows as an automatic outcome of an action. The absence of normative or legal pressure is why the deontic (D) is absent in the strategies. Therefore, in defining the type of institutions, a statement was classified as a rule when a tangible sanction was evident from existing legislation. In the case of an emotional sanction, the statement was classified as a norm. Otherwise, the statement was a shared strategy. Basurto et al. (2010, p. 526) outlined the following six steps for applying the ABDICO syntax to written documents:

1. *Identify and read all definitions, titles, preambles, and headings*.
2. *Identify sections and subsections of the bill as initial units of observation*. The (sub)sections are given headers called "outline indicators". The outline indicators need to separate the sections from the sub-sections, and the sub-sections from their own sub-sections to create the units of observation. These units of observation are temporary and may be divided into additional units when more than statement is identified within them.
3. *Subdivide all initial section or subsection units from step 2 that have multiple sentences into sentence-based units of observation.*
4. *Code the units of observation following the ABDICO syntax*.
5. *Code all units of observation as rules, norms, or strategies*.
6. *Subdivide all sentence-based units of observation* that have more than one rule, norm, or strategy into separate units and recode, following the ABDICO syntax as rules, norms, or strategies. For instance, if two institutional statements can be identified in a single sentence, then these are studied as two units, not one.

3.3.2 Identifying institutional statements from interviews

Existing literature has provided researchers with guidelines for deriving institutional statements from written documents. However, no clear steps were provided for this process for interview transcripts. Watkins & Westphal (2016) is one study where the authors gave examples of how interview quotations could be rewritten as institutional statements. However, there was no series of steps which demonstrated this. Therefore, I propose the steps given in Table 9 for formalizing institutions from interview transcripts. An example of its application is given in Appendix C.

Table 9: the steps for identifying institutional statements from interview transcripts

Step	
1.	Identify sentences as initial units of observations.
2.	Mark the verbs in case they have an action (the "what" in a sentence) along with them in each sentence. Also mark the action.
	If the action is a pronoun, look at surrounding sentences and write down the noun that the pronoun is referring to. Example: 1. The process is very simple, in the first place we **turn to the analysis** of Deltares and Royal Haskoning. 2. They provide **an initial overview of the flood risks** in the ports' area, in this case the Maasvlakte area. 3. We have done **this** for every area outside of Dordrecht… Unit of observation 3, **this** refers to the aim, so what is done according to the sentence. **This** is referring to the analysis (mentioned in unit of observation 1) about the flood risks in the Ports' area (mentioned in unit of observation 2).
	If there is no action along with the verb, you do not have a statement, but you have identified a piece of information, a description in your case. Example: 1. We **have** extensive contact with the Municipality, there **is** a lot of contact. 2. But there is often no clear answer - **it is** often more of a political solution. The units of observations contains two verbs, **have** and **is**. However, while the first unit describes the action of having extensive contact, the second unit is a description of a specific situation.
3.	Mark the subject as well in each sentence. Write down the attribute and aim from these marks. If the subject is a pronoun, try to specify the noun it is referring to by looking at surrounding sentences.
	If the subject is an animate noun and conducts the action, label this subject as the attribute [A]. Label the action they are conducting as the aim [I]. Example: 1. **We** also **had sessions** with RWS, with Ministries together, but also with our counterparts in Belgium and Luxembourg to **see what the impact would be on our freight infrastructure if we were to have climate problems**, especially in the border areas or in near Rotterdam ports or Antwerp ports. In this unit of observation, **we** refers to an animate attribute [A] (in this case it was the rail network operator), who participates in sessions to analyse the impacts of climate problems on the freight infrastructure [I].

If the subject is inanimate noun and conducts the action, this sentence might be providing information for another institutional statement, as an outcome or condition for example. It is also possible that you have not found an institutional statement, but some information regarding your case.

Example:
1. And if for example, water flows under the **cranes**, **they might start shifting** and the entire cargo is gone.

In this unit of observation, **cranes** are the subjects that are shifting. The unit of observation is therefore not an institutional statement, but it does provide information on causal consequences of actions.

4. Mark de conditions under which the actions are conducted in each sentence.

5. Mark the object in the unit of observation.

6. Add, further specify, or rewrite components in each unit of analysis by looking at information in the surrounding sentences (the other units of analysis).

7. Determine the deontic for every statement so far.

8. Determine the presence of any tangible or emotional sanctions in each unit of analysis.

9. Code all units of observation as rules, norms, or strategies.

If there is a tangible sanction, label the statement as a rule (ADICO). This sanction may be a fine, or withdrawal of an operating permit for instance that were mentioned by the respondents.

Example:
1. Another aspect that applies to companies is the Dutch Major Accidents Decree.
2. These are companies that work with hazardous substances, they have to submit an annual safety report and whether the risks they cause can be controlled and what they do about it, and that includes water safety.

The units of observation mention a decree that applies to companies. Since the companies **have to** report on how they handle water safety risks, it is likely that there is a tangible sanction like a fine in case this action is not done. Therefore, the following rule can be written down:

[A] BRZO-companies **[D]** must **[I]** report **[B]** the company's water safety risks **[C]** if safety report needs to be published **[O]** or else they have to pay a fine or do not receive an operating permit.

If there is an emotional sanction, label the statement as a norm (ADIC). This emotional sanction is not as straightforward to identify.

Example:
1. The intention is that that every municipality or water board maintains the same repetition times for the stress test.
2. And that makes them fairly comparable.

While the units of observation express that the same repetition times for climatic impacts ought to be maintained, there is no tangible sanction mentioned in any of the units of observations. Unit of observation 1 and 2 do mention that it is the **intention** to maintain the same repetition times because this makes the stress tests **fairly comparable**. Therefore, one can write down the following norms:

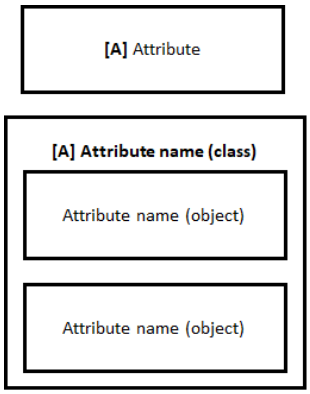
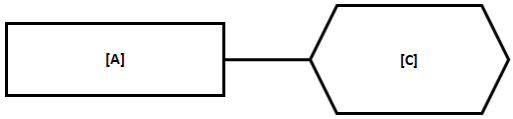
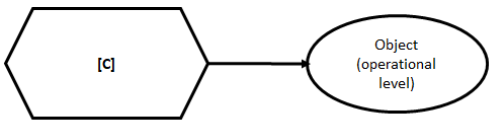
[A] Municipalities and water boards **[D]** should **[I]** maintain **[B]** the same repetition times for climatic impacts **[C]** if stress tests need to be constructed.

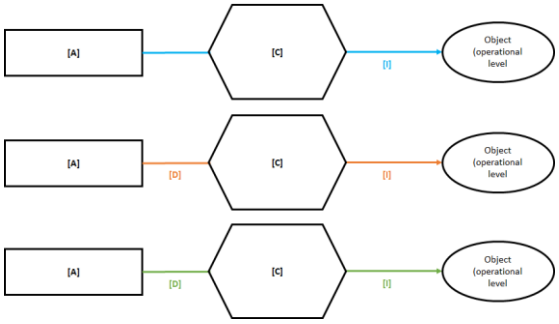
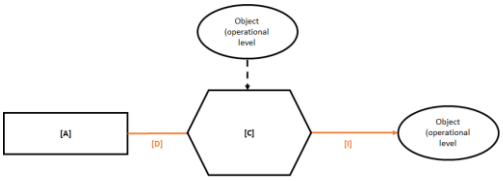
Otherwise, label the statement as a strategy (AIC). For a strategy to be shared, not only is it expected that multiple respondents mention the strategy, but also that most individuals would have to believe that most other individuals conduct a behaviour (Ghorbani et al., 2012, p. 76).

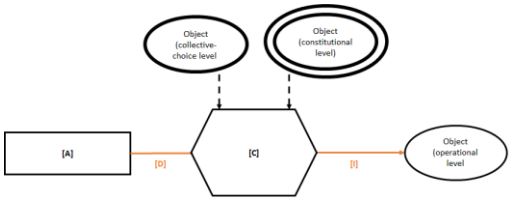
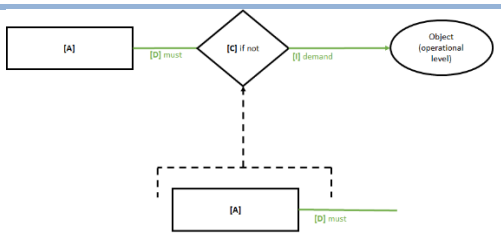
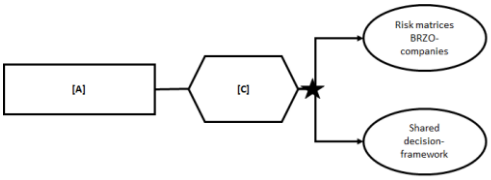
3.4 Step 4: Drawing institutional networks

INDs are graphical representation of the networks of institutional statements in an action arena (Ghorbani et al., 2020). The original steps to drawing the INDs are shown in Appendix E. Table 10 shows the new series of steps.

Table 10: the ten steps for drawing an Institutional Network Diagram (adapted from Ghorbani et al., 2020)

Steps for drawing the Institutional Network Diagram (IND)				
Step		**Concept in IAD framework**	**Concept in ABDICO syntax**	**Visual representation in IND**
1.	Define the action arena that forms the basis of the IND.	Action arena	-	Title of the IND
2.	Determine what cluster of institutional statements define the action arena.	Rules-in-use, attributes of community/ physical world	-	-
3.	Define the primary attribute(s) [A] to whom the institutional statement applies. Some statements are conducted collectively by multiple attributes. In this case, draw the individual attributes in a larger rectangle, and write down a generic name for this group.	Actor	**A**ttribute	
4.	Draw a link from the attribute to the condition, and write the condition(s) for the institutional statement. The [C] interrupts a link or arrow.	Patterns of interactions	**A**ttribute **C**ondition	
5.	Draw a link from the condition to the object of the statement. Since the object follows directly from an action in this action arena, it is an object on an operational level.	Patterns of interactions *Level* of an institutional statement	**A**ttribute **C**ondition O**b**ject	

6.	Use a colour code to distinguish between rules, norms and shared strategies and colour the link between the attribute and the condition(s), and the arrow between the condition(s) and object. In this research, rules are green, norms are orange and shared strategies are blue lines.	Rules-in-use	ABDICO ABDIC ABIC	
7.	Write the [D] deontic between the attribute and the condition(s), and the aim [I] between the condition(s) and the object. Give them the corresponding colour of the links as well. Institutional statements with no formal explicit sanction in the statement are still written as rules when the action is considered to be a formal responsibility.	Rules-in-use Outcomes	**D**eontic A**i**m	
8.	If the object of one institutional statement influences the condition(s) of another institutional statement, draw a black dotted arrow from the object of one institutional statement, to the condition(s) of the other institutional statement. If the object does not influence other institutional statements, it is the outcome of an IND.	Patterns of interactions Outcomes	Object Condition	

	If any other objects exist on a collective-choice level or constitutional level that influence the condition(s), connect them to the condition(s) with black dotted arrows as well.			
9.	In case of a formal sanction, draw a rectangular dotted line around the attribute and the deontic. Connect this to a diamond, which is part of the institutional statement which states the sanction if not conducting the aim.	Rules-in-use	**O**r else	
10.	If two or more institutional statements yield different outcomes in the same action situation, an institutional conflict has been identified. This is depicted with a black star.	-	-	

Given the original set of steps (Appendix E), several modifications have been made. First of all, the *object* component of the ABDICO syntax (Siddiki et al., 2011) has been added to the INDs (Figure 10). Adding the *object* component to the diagrams allows one to explicitly see how one institutional statement influences another institutional statement. Essentially, attributes (actors) are triggered to conduct the aim (action) of an institutional statement through the conditions. Whether conditions actually trigger the conduct of an institutional statement, is shown to be dependent on properties of the object of another statement that is connected to it. This relation is shown through the dotted arrow between the object of one institutional statement, and the condition(s) of another institutional statement. Such a relation implies that the actor conducting the first institutional statement has an influence over the behaviour of the other actor.

Second of all, the different levels (Figure 4) at which objects influence the conditions have been added to the diagrams (Figure 11). As explained before, objects are the inanimate or animate part of a statement that receive the action (Siddiki et al., 2011. They may therefore also exist on higher levels, and exert influence over the institutional statements in the operational INDs. This influence is shown by connecting objects on a collective-choice level and constitutional level with dotted arrows to the conditions(s). Including the different levels allows one to improve the current structure of the formal charts (explained in section 3.5).

Lastly, various elements of the original steps (Appendix E) have been changed so that all the institutional statements have the same construction.

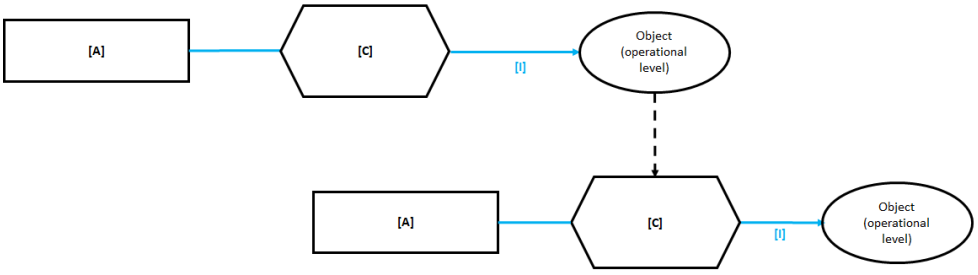


Figure 10: the construction showing the connections between two institutional statements (here, two shared strategies) in the INDs. The objects of one statement influence, or trigger, the state of conditions of other institutional statements.

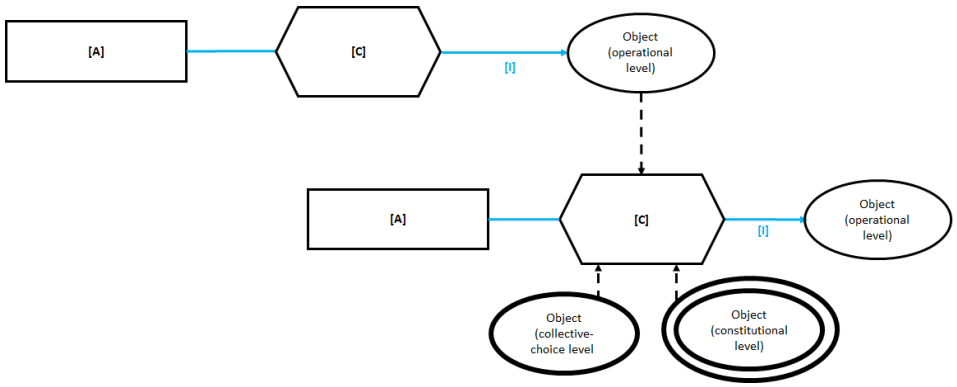


Figure 11: the construction showing how objects at different levels (operational, collective-choice, constitutional) influence the condition(s) of an institutional statement.

Example of an IND

Figure 14 shows an example of an IND. The full description of this IND given in subsection 4.2.2. This diagram shows the institutions that are relevant to the mapping of vulnerabilities in the knowledge gathering action arena (step 1). The example includes 12 institutional statements (step 2), which follows from the number of aims represented in the diagram. There are three primary attributes in the diagram: the Port of Rotterdam and the Municipality of Rotterdam as a collective actor, the Royal Dutch Meteorological Institute, and the Ministry of Infrastructure and Water Management (step 3).

In the example of the institutional statement about the Port of Rotterdam and the Municipality of Rotterdam, it is shown that they engage in the knowledge gathering for climate adaptation together. If risk aware (step 4), the partners will commission specifications for a flood probability analysis (step 5). When these specifications are available, it is Royal Haskoning DHV who conducts this research for the Port and the Municipality. The relation between these two institutional statements is shown through a dotted arrow from the 'flood probability analysis specifications' to the condition directly under this object. Royal Haskoning DHV, having accepted the task to make the flood probability analysis, is activated to construct the analysis.

This is written as the following institutional statement (rule): [A] Royal Haskoning DHV [D] must [I] construct [B] the flood probability analysis [C] if the flood probability analysis specifications are available, and if new climate change scenarios are published (step 6 and 7). The object of this institutional statement, the flood probability analysis, is then connected to the condition related to the follow-up action of the Port and the Municipality of Rotterdam (step 8).

3.5 Step 5: Institutional network analysis

For the analysis of the networks, there are three ways in which the INDs can be analysed (Ghorbani et al., 2020). One can study institutional conflicts, calculate institutional network metrics, and link institutional statements from different INDs together. While these steps can also be conducted for the improved versions of the INDs, the analysis was conducted for the original constructions of the INDs due to time constraints of this study. All original INDs can be found in Appendix E. Since the institutional statements and relations between them in the improved version of the INDs are almost identical to the original constructions, the results of the analysis still apply to the improved versions of the INDs.

In the case of an institutional conflict, two or more institutions with different outcomes guide actor behaviour. In this case, the researcher has to learn which institution is followed over the other, and under what circumstances.

Table 11: network metrics in the IND.

Network metrics and performance		
Concept		
Connectedness: density	**Centrality**	**Embeddedness**
	Calculation	
Number of actual links divided by the maximum possible number of links (only including attributes as nodes) (Janssen et al., 2006)	Number of links per attribute, divided by the average number of links (Janssen et al., 2006)	Number of links per attribute (connecting two attributes), divided by the total number of links per attribute (connecting to attributes or outcome nodes)
Range: [0,1] A score of 1 is complete density, a score of 0 is no density at all	Range: [0, ∞] A score above 1 means that the node has a high rank on centrality, a score below 1 means that the node has a low rank on centrality	Range: [0,1] A score of 1 means complete embeddedness, a score of 0 means no embeddedness at all
Link to performance		
No straightforward link between density and performance or resilience of the network.	No straightforward link between centrality and performance of the network.	Insight in decision making space of attributes; Low embeddedness of an attribute implies that the circulation of information is more difficult, and also implies less social constraint on individuals which may lead to corruption.

Furthermore, network metrics (e.g. density, centrality and embeddedness) can be calculated to assess the performance of the current network (Table 11). The network metrics are useful for giving recommendations to policy-makers on how to improve the current performance in the current institutional reality. Moreover, the INDs can be linked to each other so that the connections between the INDs can be studied as well rather than only the connections between individual institutional statements within one IND. First of all, the INDs in this research are based on the three phases of climate adaptation in the Netherlands.

These phases are theoretically speaking a sequence and help to understand the links between the INDs. Second of all, the outcomes of one IND can serve as input for another IND. For example, if an analysis of climate impacts by an infrastructure owner is conducted in one IND, this may be the input for dialogue with other infrastructure owners in another IND.

Apart from these three ways of analysing the INDs, I propose that analysts can also gain insights on the power relations and dependencies between actors by drawing *aggregated formal charts* for each IND. Consider the connection between the two institutional statements in Figure 12. The decree on external security of establishment, essentially gives the authority to the Province of South-Holland to set acceptable groups risks. The group risk is the cumulative probability per year that at least 10, 100 or 1,000 persons die as direct result of their presence in a company's sphere of influence and unusual occurrence within that company involving a dangerous substance or hazardous waste (Port of Rotterdam, Municipality of Rotterdam, & RWS, 2016). For the construction of a shared decision-framework, the Port of Rotterdam and the Municipality of Rotterdam need to know about these acceptable risks. The Province of South-Holland therefore exerts influence over the Port and the Municipality, because it impacts how the shared decision-framework is to be constructed.

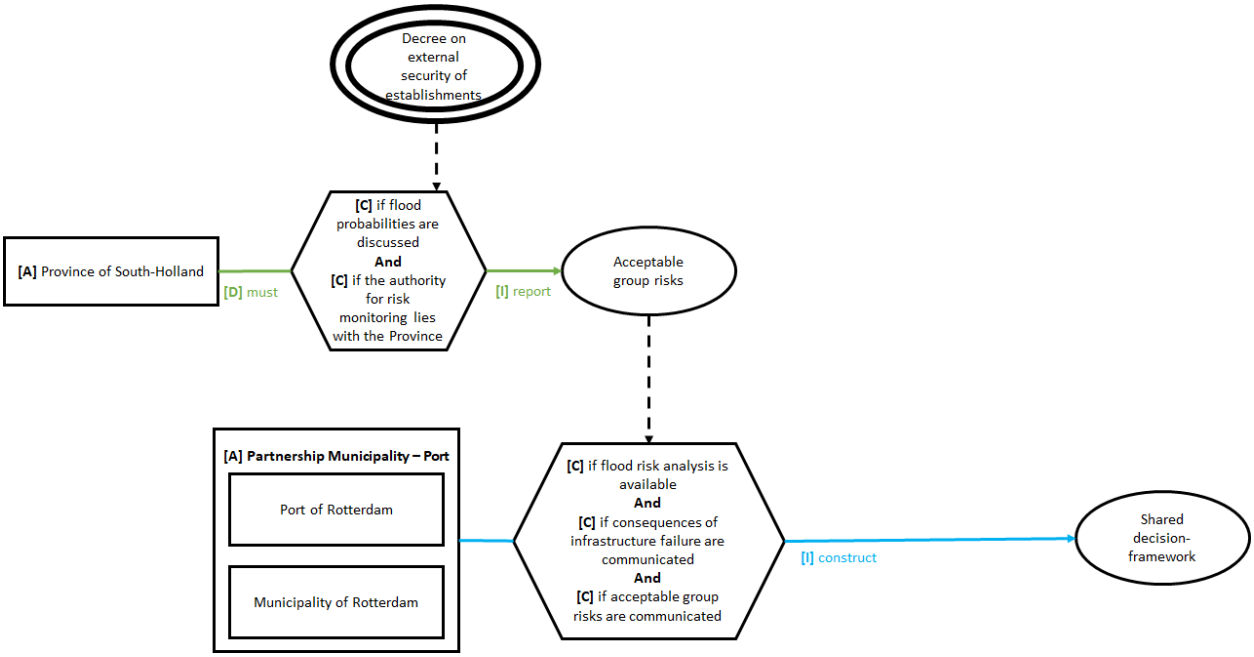


Figure 12: two institutional statements (from the IND of risk dialogue I)

This influence, through the decree on an constitutional level, can be summarized, as shown in Figure 13. The arrow shows that the Province of South-Holland influences the Port and the Municipality through the decree on external security of establishments. This construct can now be used as a convention for formal diagrams. For all the relations, it is shown according to what institution influence is exerted, and in which particular action arena this is the case.

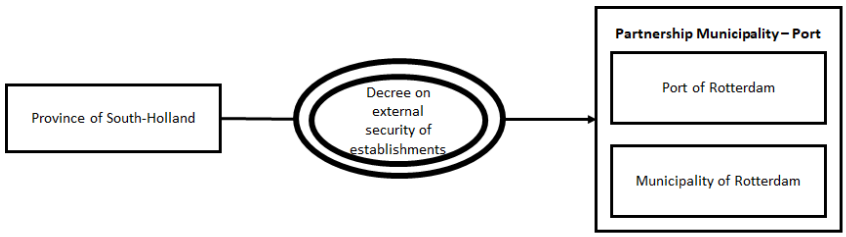


Figure 13: the influence of the Province of South-Holland on the Port and the Municipality based on the decree on external security of establishments.

3.6 Verification and validation

For improving the INA method, two sessions of a total of four hours were carried out with Dr. Pieter Bots (TU Delft). During the sessions, the original INDs and the elements that had been used to visualize institutional statements, were reviewed and iteratively improved. For validating the results of the network analysis, expert validation was to be conducted with the stakeholders who were interviewed. The respondents were contacted through email and informed about validation sessions which would take place with all the interviewed respondents. However, due to the corona-outbreak, it was not possible to conduct the sessions as planned, and the final conclusions following from the analysis were planned to be shared with the respondents who took part in climate adaptation efforts surrounding the Port of Rotterdam. Based on the reactions, certain elements of the diagrams were changed.

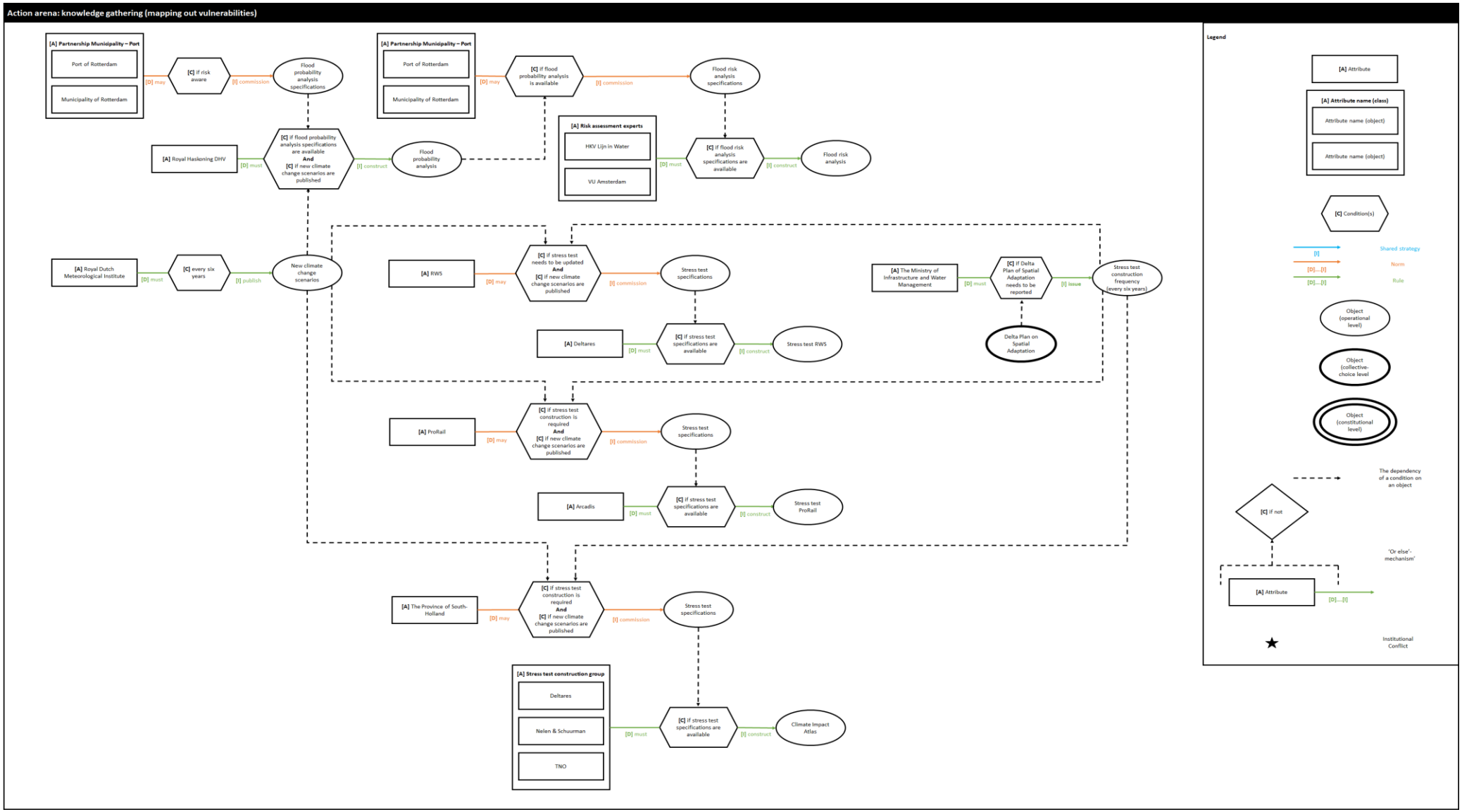


Figure 14: an example of an Institutional Network Diagram.

4. Institutional Network Analysis (INA) surrounding the Port of Rotterdam

This chapter contains the application of the Institutional Network Analysis (INA) method on the case of transport infrastructures connected to the Port of Rotterdam. This section starts with several highlights from the discourse analysis (section 4.1). Next, the Institutional Network Analysis will be applied to the Port of Rotterdam (section 4.2). First, the scope and assumptions are explained. Next, the institutional statements found in written sources and the interview transcripts will be presented in the INDs. Subsequently, the analysis of the original INDs is be shown in section 4.3. The focus is on three aspects: the identification of potential institutional conflicts, the network metrics, and the linkage of institutional networks. The chapter ends with important recommendations for the improvement of climate adaptation efforts in the Netherlands (section 4.4).

4.1 Highlights of the discourse analysis

In this section, several important conclusions from the discourse analysis are given. These conclusions help in constructing the Institutional Network Diagrams (INDs) and help in giving recommendations to policy-makers.

4.1.1 Isolated and diverse research efforts

"When the parties conduct the stress tests for assessing the impacts of climate change, they do not incorporate the interdependencies between infrastructures, but focus on the infrastructures they own."

Infrastructure owners mentioned that they communicated with each other on a regular basis. This is because they are responsible for managing the respective infrastructures, and need to be aware of problems that infrastructure users might experience, especially for climatic impacts which were less prevalent in the past such as heat and drought. Rijkswaterstaat (RWS) mentioned that during the drought in 2018, there was regular contact with waterway users about the bottlenecks they experienced: transhipment of containers, supplying raw materials, and carrying intermediary and end products were all difficulties waterway users were facing. The communications are therefore in particularly conducted for operational purposes. However, when parties conduct stress tests for understanding the impacts of climate change, they do not incorporate interdependencies between infrastructures, but rather focus on the infrastructures they own. Parties have different working styles in assessing the impacts on infrastructures as well. The Province of South-Holland started with a "quick-scan" for the provincial roads and waterways through a climate impact atlas. Based on the results of this quick-scan, a deeper stress test would be made at the most vulnerable locations. ProRail had a similar approach for the railways. Rijkswaterstaat however, chose several spots in the Netherlands for an immediate in-depth analysis, while for other areas, a quick-scan was made. The public parties are all conducting stress tests in parallel at the moment, so that they exchange information on how to construct a stress test for instance. Despite these information exchanges, the stress tests also do not contain any assessment of effects from one infrastructure on the other. With respect to the knowledge gathering, the Port of Rotterdam takes part in the working group of Rijnmond-Drechtsteden, a subprogramme of the Water Safety Delta Plan in the Delta Programme. Contrary to the stress tests being constructed by infrastructure owners in the Delta Plan of Spatial Adaptation, the Port of solely focusses on sea-level rises in the tests.

4.1.2 No common framework for risk assessment

"The absence of a common systematic approach for prioritizing and weighing different short-, mid-, and long-term impacts hampers the translation of the found risks to an actual implementation agenda."

Several stakeholders mentioned that the variety in research efforts on an operational level make it difficult to compare the results of the different stress tests. What makes the whole decision-procedure more complex however, is the way in which parties *perceive* and *assess* the risks. For climate adaptation, the Ministry of Infrastructure and Water Management decided not to determine any fixed objectives or standards to define climate-resistance. The purpose of this absence is that stakeholders come to an agreement on what climatic impacts they find acceptable for different infrastructures at different areas in the Netherlands. This implies that every stakeholder may develop its own standards for risk severity and decide by itself what is severe and what is acceptable. So while the impacts of climate change are known, not all stakeholders have the same risk perception.

During risk dialogues, stakeholders with different risk dialogues need to form a common ground on which risks in the environment need to be prioritized. However, respondents mentioned how this weighing of short-term and long-term risks is problematic during these dialogues. An example that a respondent gave was that during one risk dialogue, the priority was given to preserving the accessibility of hospitals over improving the functioning of the rail network over a longer period of time. This was because assuring the accessibility of hospitals would generate immediate positive short-term benefits for the health care sector. The absence of a common systematic approach for prioritizing and weighing different short-, mid-, and long-term impacts hampers the translation of the found risks to an actual implementation agenda.

This problem is more common on a national scale than during risk dialogues on a local scale. On a local scale, actors working on projects have longer histories of working together and have developed a deeper understanding of the risks over time. Moreover, the solutions they discuss during their risk dialogues are to be implemented on a relatively smaller scale than solutions for national infrastructures. The larger the network, the more actors will have a stake, and the more negotiations need to be conducted, the more risk perceptions of other will be needed to account for, and the longer it takes to form a common ground on the impacts and necessary measures.

4.1.3 No common perception of urgency of climate adaptation measures

"These climatic hazards or disasters sometimes have very small probabilities as compared to events such as traffic accidents, which may give off the impression that they do not require immediate action"

Decision-makers and their asset managers often have different perceptions of the urgency of climate adaptation options. Urgency here refers to the need to implement climate adaptation options: one may implement measures immediately, or choose to defer action to a later point in time. In order to determine the urgency, one may look at the probability that a climatic hazard or disaster may occur. These climatic hazards or disasters sometimes have very small probabilities as compared to more common events such as traffic accidents. This may give off the impression that these hazards do not require immediate action. Asset managers may therefore be more likely to accept climatic hazards as compared to the actors who are more involved in strategic decision-making for the long-term.

4.1.4 Ambiguity on financial responsibilities

"Every infrastructure is situated in an area with multiple ownerships, and sometimes, the cause of the climatic hazards leads to the conclusion that interventions in the areas of other stakeholders are necessary."

While research efforts focus on finding the vulnerabilities on separate infrastructures, this does not mean that measures which can reduce these problems are only to be carried out by the actor who perceives that the vulnerabilities need to be tackled. Every infrastructure is situated in an area with multiple ownerships, and sometimes, the cause of the climatic hazards leads to the conclusion that interventions in the areas of other actors are necessary. Even if there is agreement on what the urgent risks are, the most important question is about who is appointed as the financial bearer of these risks: the one who perceives the risks, or the one who own the infrastructure where measures may reduce the risks?

4.1.5 National coordination, prioritization and specification of ambitions for climate adaptation is desirable

"Having a common goal, or common criteria in mind to assess the risks significantly supports the decision-making process and the negotiations about risks and options to implement."

What was particularly interesting was the tension between two lines of thought which came forward throughout the interviews. On one hand, almost all the respondents emphasised that climate adaptation is characterized by customisation. Which criteria play a role in the risk assessment and which measures are deemed to be effective are site-specific. This is why there are no fixed standards to which infrastructure owners have to comply. The idea is that what is acceptable must follow from the risk dialogues. On the other hand, respondents mentioned that having a common goal, or common criteria in mind to assess the risks significantly supports the decision-making process and the negotiations about risks and options to implement. It was found to be desirable to receive more fixed guidelines, especially from the national government.

4.2 Institutional Network Analysis (INA)

In this section, the application and results of the Institutional Network Analysis (INA) are given. Subsection 4.2.1 explains what action arenas are selected and what other assumptions underlie the construction of the INDs. The two consecutive subsections show two INDs in detail (subsection 4.2.2 and subsection 4.2.3). The other INDs can be found in Appendix E.

4.2.1 Action arena selection and assumptions

Action arenas and the INDs

As mentioned before, the Delta Plan of Spatial Adaptation has distinguished three phases which need to be conducted before the end of 2020, namely: knowledge gathering, conducting risk dialogues and, and drawing up an implementation agenda. Based on these phases, the following action arenas were formed.

- Knowledge gathering

During the knowledge gathering, the impacts of climate change are mapped through different forms of research. This task is often delegated from infrastructure owners or governments to research institutes and engineering firms who offer these services. After the impacts are mapped, the maps show where the climate hazards are very severe and where the infrastructures may be vulnerable. Vulnerable here means that the highest category on a scale showing the severity of an impact applies.

For example, if there is a scale showing extreme rainfall, the highest amount of rainfall is likely to occur in an area. Whether this vulnerability poses a risk that needs to be prioritized is something that actors need to determine together during the risk dialogues. The entire knowledge action arena for the knowledge gathering has been visualized in two INDs for better readability. Note that both diagrams belong to the same action arena. The first diagram shows how research efforts are initiated (subsection 4.2.2). The second diagram depicts at what levels of climate hazards infrastructures were potentially raked as "vulnerable" by the Province of South-Holland, ProRail, and RWS (Appendix E). The reason why these three actors are shown in the IND is because only they had made this information from their publicly available. Not all the actors involved had made their stress test publicly available or they were still constructing the stress test. In the case of ProRail for example, the stress test was not put online, but the information about categories showing the vulnerability of the rail infrastructure for climate change could be retrieved in a special guide related to sustainable project management (as explained in subsection 4.2.2), but this was not the case for other parties. RWS was constructing both stress tests for the national waterways and the roads, but only the latter was finished and shared for this research only.

- Risk dialogue I

The risk dialogue phase has been split in two separate action arenas because in the case of the Port of Rotterdam, the risk dialogue is conducted in two workshops with very different focusses. Workshop I is meant as the starting point of the information exchange. All the actors who have conducted research and are invited by the Port of Rotterdam are asked to provide input on the vulnerabilities they have found. In this workshop, no adaptation strategy is formulated yet, but the consequences of the vulnerabilities are communicated between the actors. Based on the findings, a shared decision-making framework is constructed, showing the order sizes to acceptable economic, social, and environmental consequences of floods in the area.

- Risk dialogue II

In workshop II, parties use different decision-making frameworks, such as risk matrices, to determine which measures ought to be implemented. Since this workshop is more focussed on choosing paths for adaptation, it is drawn as a separate action arena in the risk dialogue phase.

- Drawing up an implementation agenda

Drawing up an implementation agenda here means that measures are being planned out. From the interviews, it follows that in reality, none of the actors are in a phase were measures are actually being implemented at the moment. Therefore, two types of measures are incorporated in this IND which followed from the interviews, and which have the potential to be implemented in the context of climate adaptation surrounding the Port. The first measure relates to responding to water hazards during emergency situations at the Port. The second type of adaptation measure relates to adaptation measures which protect infrastructures against water hazards.

Assumptions

Several rules do not have formal sanctions, but since they are formal responsibilities, it would not be fitting to put them in the INDs as norms. Therefore, these institutions have also been shown as rules. What is also important to point out is that the respondents expressed that the phases for climate adaptation are not linear, but that they are iterative and feed into each other. For example, when parties have conducted risk dialogues, they might find that certain aspects of the stress tests they made in the knowledge gathering process need to be tweaked. Moreover, the risk dialogues themselves are rather a format in which dialogues are conducted for different infrastructural projects, rather than specific, fixed moments in time.

However, for drawing the diagrams, it is assumed that these phases are linear and separate from each other. Therefore, the view drawn in the INDs is more static than reality.

In studying climate adaptation efforts of different infrastructure owners surrounding the Port of Rotterdam, the focus is on the actors whose infrastructures are directly connected to the port. One of the pilot areas where parties' infrastructures come together in this way is the Botlek and Vondelingenplaat area. Important actors for this area are shown in Figure 15. In reality, more actors are involved since other areas of the Port are not taken into consideration, and the focus here is on infrastructure owners.

Figure 15: the main public and private parties with an interest or stake in the outer-dike area of the Port of Rotterdam (based on Kennisportaal Ruimtelijke Adaptatie, 2018).

4.2.2 Institutions in knowledge gathering

The first general phase in climate adaptation in the Netherlands is knowledge gathering. In this phase, different parties map the vulnerabilities as a result of climate change. These vulnerabilities are then used to assess the impacts potentially resulting from them. For depicting the institutions that guide this phase, the following written sources from the desk research were used in particular.

Guide on how to making stress tests

As part of the Delta Plan for Spatial Adaptation, stress tests are made nationally by infrastructure owners, regionally by provinces and water boards, and locally by municipalities. Stress tests enable the mapping of vulnerabilities on regional and local levels for each of the four major effects of climate change (Table 1). Every 6 years, the stress tests are updated based on new climate change scenarios of the Royal Dutch Meteorological Institute. To safeguard the comparability between the different stress tests, the platform of the Delta Plan of Spatial Adaptation has published several standards for the procedure of carrying out the stress test (Kennisportaal Ruimtelijke Adaptatie, 2020a). It does not prescribe the whole procedure in detail, but advices parties on their underlying assumptions, input data, calculations, and approaches to communicating the results of the test. For example, including the "W_H" and "G_L" scenarios is generally expected because they can be easily combined with socio-economic scenarios to assess the potential consequences of the vulnerabilities. It is possible to deviate from these prescriptions by adding climatic impacts to the four major effects, or to work with different assumptions for example. In this case, the actor must report why it decided to deviate.

Publicly available stress tests and climate impact atlases

Stress tests generally include two types of visualizations: the first type of visualization shows the climatic effects, so where the water hazards, drought, heat, and floods are at their highest levels. In this action arena, the climate impact atlas of the Province of South-Holland was published online (Province of South-Holland, 2020), and the stress test for the national road network by RWS was sent to the researcher (RWS, 2020). The stress tests were used to assess how every climatic hazard was quantified, and how the vulnerabilities were shown in the maps.

Water Safety Report of the Botlek and Vondelingenplaat area

In general terms, the Port of Rotterdam has a similar approach as outlined in the Delta Plan on Spatial Adaptation. The knowledge gathering also includes mapping the impacts of climate change. However, within the Delta Programme, the Port of Rotterdam is not actively involved in the Delta Plan on Spatial Adaptation, but in the Delta Plan on Water Safety (section 2.1.2). The Rijnmond-Drechtsteden programme, part of the Delta Plan for Water Safety, focusses exclusively on flood risks, since the Port is situated in outer-dike areas, and is therefore not insured against flooding. The full report on "Water of the Botlek and Vondelingenplaat area" summarizes the modelling of flood risks, communicating these risks with private companies and infrastructure owners, and the trade-off which was collectively made between different adaptation measures (Port of Rotterdam, Municipality of Rotterdam & RWS, 2016).

Other guides and strategies on climate adaptation

For several stakeholders, the stress tests were not publicly available or were being updated. The Municipality of Rotterdam also makes a stress test, but this was not published. In the case of railway owner ProRail, the stress test was also not available, but there was a guide which showed different vulnerability categories for climatic hazards (ProRail, 2019a).

The IND in Figure 16 shows three primary actors: the Municipality of Rotterdam and the Port of Rotterdam as one actor, and the Ministry of Infrastructure and Water Management, both initiate the efforts for climate adaptation. Apart from these actors, there are Infrastructure owners whose infrastructures are connected to the Port of Rotterdam: ProRail (rails), RWS (national roads), and the Province of South-Holland (regional roads and waterways). These parties delegate the task of constructing stress tests, or analysing climatic hazards, to external partners, like Deltares, Arcadis, and Royal Haskoning DHV. These research institutes and engineering firms base their analysis on the scenarios of the Royal Dutch Meteorological Institute, who publishes four climate change scenarios:

- W_H: average global temperature rise in 2050 is 2°C compared to 1981-2010, and increased drought occurs.
- W_L: average global temperature rise in 2050 is 2 °C compared to 1981-2010, no increased drought occurs.
- G_H: average global temperature rise in 2050 is 1°C compared to 1981-2010, and increased drought occurs.
- G_L: average global temperature rise in 2050 is 1 °C compared to 1981-2010, no increased drought occurs.

There are several differences in the working style of the actors involved. The infrastructure owners conduct the stress tests because this follows from the policy of the Delta Plan on Spatial Adaptation as developed by the Ministry of Infrastructure and Water Management. The Port of Rotterdam is not actively involved in the Delta Plan on Spatial Adaptation, and therefore does not follow the same guide on stress test construction. The focus for the Port of Rotterdam is on sea-level rise, since the Port is situated outside of the dikes. This means that the companies operating at the Port, the Port of Rotterdam, and other users of the Ports' area bear the risks of water hazards due to floods. This is an important motive for the Port to engage in the knowledge gathering. Initially, Royal Haskoning DHV is requested to provide an flood probability analysis, which shows the areas being damaged for floods with different probabilities of occurring. Next, the information is used to make a flood risk analysis for the risk dialogue.

However, the climate impact atlas and the stress tests for infrastructure owners who operate according to the Delta Plan on Spatial Adaptation, do not have the same level of detail, or same focus with regards to the climate hazards being accounted for. A climate impact atlas is known as a "stress test light", and generally serves as an assessment of the impacts on a high level of aggregation. Based on this analysis, areas which are particularly vulnerable are selected for a deeper analysis of the impacts for infrastructures in a stress test. Both ProRail and RWS choose different focuses for the stress tests, and the scenarios they consider. Moreover, from the interviews, it became evident that RWS focusses on several critical areas in its network already, while ProRail makes a chooses critical areas for an in-depth analysis after the stress test is made. On one hand, one may argue that the differences in working styles do right to the diversity of infrastructures. On the other hand, working according to the same assumptions makes the comparison of the results easier and the risk perceptions more aligned. Either way, the IND for knowledge gathering shows that research efforts are conducted in isolation from each other. This does not mean that there is no communication at all between the parties, but that the communication does not aim at understand the impacts that infrastructures have on each other.

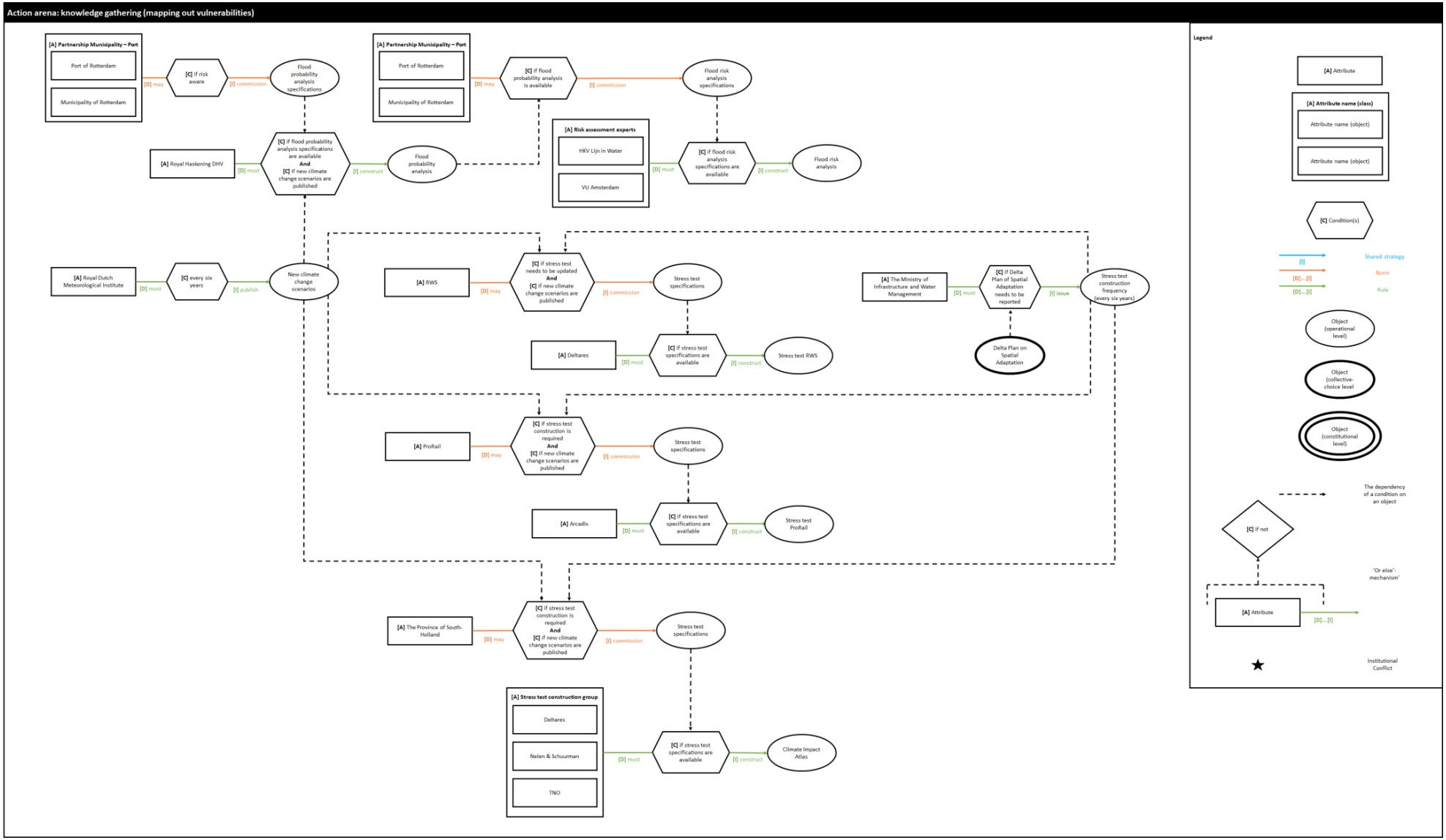


Figure 16: IND for knowledge gathering (mapping out vulnerabilities).

4.2.3 Institutions in the risk dialogue (workshop I)

The second general phase in climate adaptation in the Netherlands is conducting risk dialogues. In this phase, different parties share their assessments and perceptions of critical vulnerabilities. For depicting the institutions that guide this phase, the following written sources from the desk research were used in particular.

Water Safety Report of the Botlek and Vondelingenplaat area

The risk dialogue for the Botlek and Vondelingenplaat area consisted of two workshops. Therefore, the risk dialogue phase is split in two action arenas: workshop I (Figure 17), and workshop II (Appendix E). During workshop I, the Port of Rotterdam and the Municipality of Rotterdam share information about the flood probabilities. Infrastructure owners, and private companies provide input about likely consequences associated with each flood, its severity, and its probability. Based on the information about the consequences, the Port of Rotterdam and the Municipality of Rotterdam construct a shared decision-framework, as shown in Table 12 to have a common overview of the economic, societal, and environmental consequences, and their acceptability.

Table 12: the proposed shared decision-framework by the Port of Rotterdam (based on Port of Rotterdam, Municipality of Rotterdam, & RWS, 2016, p. 39)

Number of deadly casualties	Total economic damage	Scale of environmental damage	Acceptable chance of failure (per year)
1	0,1 million euros	Area of impact has a span of < 1 km	1/100
10	1 million euros	Area of impact has a span of < 20 km	1/1000
100	10 million euros	Area of impact has a span of < 50 km	1/10000
1000	100 million euros	Area of impact has a span of >= 50 km	1/100000

Guide on conducting risk dialogues

The platform for the Delta Plan on Spatial Adaptation gives general guidelines for how to prepare, conduct, and complete a risk dialogue (Kennisportaal Ruimtelijke Adaptatie, 2020b). Most organisations have an internal risk dialogue first, risks are assessed with other departments in the same organisation or a selection is made of parties to invite to the external risk dialogue. During the risk dialogues with external parties, several important topics which were mentioned were making a trade-off between the different vulnerabilities, searching for additional information to explain the vulnerabilities, and determining the acceptability of the risks involved. For determining the risk acceptability, parties may use tools such as risk matrices. It is mostly up to the participants and the organiser of the risk dialogue how they will give substance to the dialogue.

Dutch Major Accidents Decree ("Besluit Risico's Zware Ongevallen")

The European Commission has formulated the Seveso III directive. While the directive is not directly related to climate change, it obliges companies in EU-countries to draw up a safety report of the quantity of hazardous substances exceeds a certain level. One of the most important risks that is governs, are risks related to flooding (Government of the Netherlands, 2020a). This regulation therefore impacts the company behaviour in managing climate change risks.

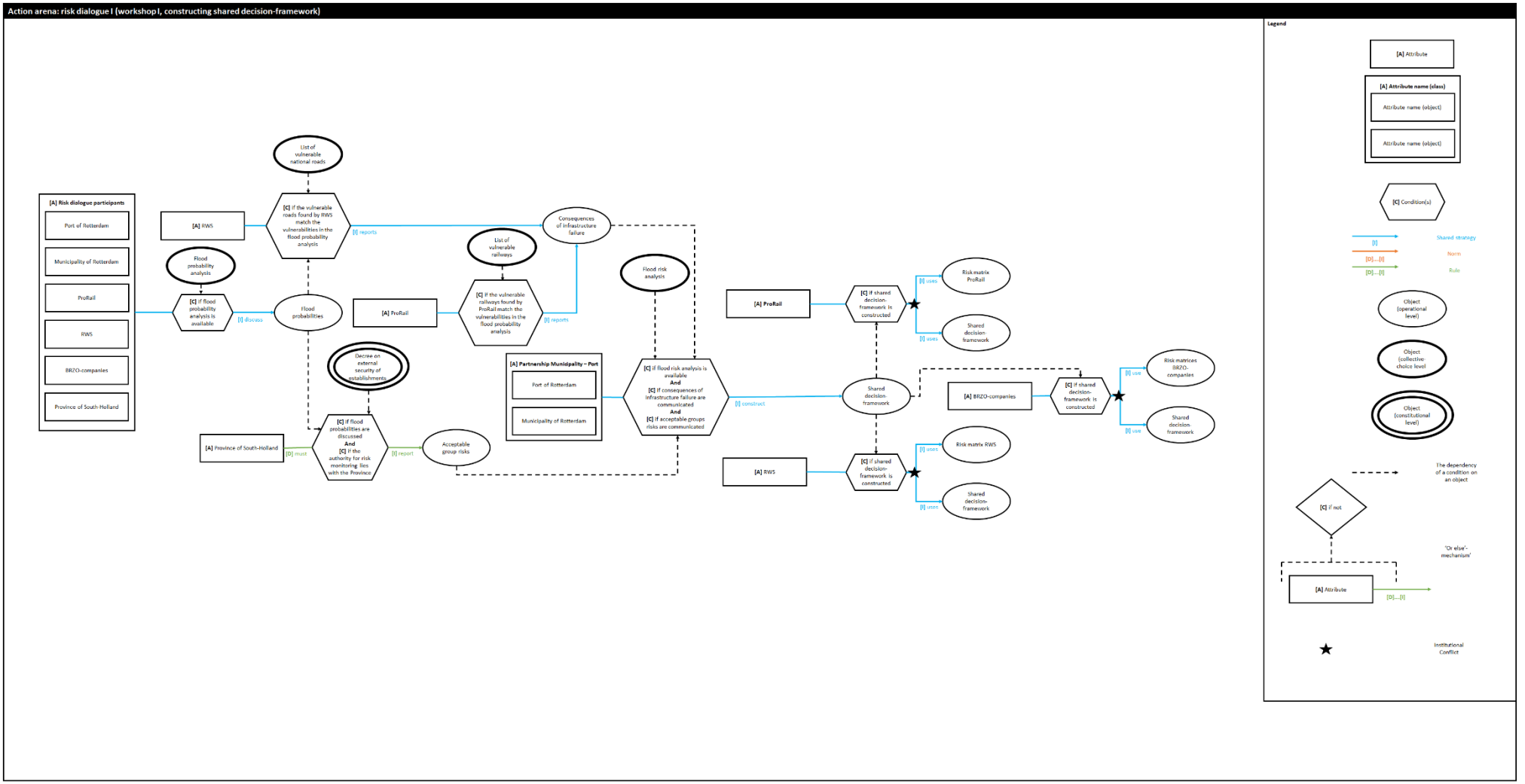


Figure 17: IND for risk dialogue I.

The relations between the institutions as shown in Figure 17 show that the results of the flood probability analysis are first discussed between the participants of the risk dialogue. The infrastructure owners then validate this information by looking at the vulnerable roads or rails they had identified through their own stress tests. If the areas where vulnerabilities are found overlap, RWS and ProRail explain what kind of damage one may expect if the floods in the scenarios were to occur. Another consequence which is communicated is the acceptable levels of individual and group risk which apply to BRZO-companies by the Province of South-Holland. The individual risk is the maximum permissible risk of death as an individual during a flood with a probability of 10^{-5} per year (low probability). The group risk is the cumulative probability per year that at least 10, 100 or 1,000 persons die as direct result of their presence in a company's sphere of influence and unusual occurrence within that company involving a dangerous substance or hazardous waste (Port of Rotterdam, Municipality of Rotterdam, & RWS, 2016). Based on this input, a shared decision-framework (Table 12) is constructed for the assessment of the risks.

The IND shows that the Port of Rotterdam and the Municipality of Rotterdam have an important coordinating role, and attempts to align the risk perceptions of the actors involved together. It does so through the formulation of a shared decision-framework by considering the input of the parties involved. However, there are several points one can notice in here. The first point is presence of institutional conflicts in this action arena, since apart from the shared decision-framework, parties have their own risk matrices as well. This conflict is addressed in subsection 4.3.1. The second point to notice is that not all the categories of climatic impacts are discussed during the risk dialogue: the focus on drought and heat is missing, and their impacts are also not incorporated in the shared decision-making framework (Table 11). While risk dialogues may be arranged for different climatic hazards, and different areas, it is important that potential knowledge gaps climatic impacts are not neglected. Lastly, the focus of the risk dialogue was on the Botlek and Vondelingenplaat area, and the infrastructures directly connected to this area. However, adjacent areas might have infrastructures which are equally important in enabling transportation to the hinterland. However, the participants of the risk dialogue are almost all parties who operate within or surrounding the industrial area of the Port.

4.3 Analysing the INDs for climate adaptation

The previous section showed two of the four INDs drawn in this research. In this section, the analysis of the original INDs (Appendix E) is shown in terms of the found institutional conflicts (section 4.3.1), network metrics (section 4.3.2), and links between the INDs (section 4.3.3).

4.3.1 Institutional conflicts

Table 13 shows the institutional conflicts identified in the action arena of risk dialogue I (Figure 17) and drawing an implementation agenda (Appendix E). It shows which institutions conflict with each other. To understand whether and under what circumstances actors give prevalence to one institution over the other, the interview transcripts are reviewed to find information that may clarify the institutional hierarchy.

Table 13: the identified institutional conflicts from the INDs.

IND	Institutions	Further analysis
Risk dialogue I (Figure E.5)	(N10-12)-(S29-31) Norm: RWS/ProRail/BRZO-companies may base acceptable chance of infrastructure failure on shared decision-framework if shared decision-framework is available. or Strategy: RWS/ProRail/BRZO-companies does not base acceptable chance of infrastructure failure on shared decision-framework if shared decision-framework is available.	When returning to the interview data, the following findings came forward: *"The assessment framework that the port authority has developed is actually an attempt to develop a look at a kind of measure for what we find bad and what we do not mind, what we find acceptable and what we do not find acceptable. There were those workshops that had been focused on before, with those companies to determine - what do we mind and when not and what would we do with it?"* *"We made an assessment framework because this did not yet exist for outer-dike areas. So we made an assessment framework ourselves to determine at what moment and in which area or infrastructure you need to take measures. Doing that, you come to a strategy."* Because the Port of Rotterdam is positioned in outer-dike areas, there are no fixed regulations for water safety, and the framework is used as a tool to help give the different parties an overview of the scale of the impacts. Based on the data, it is assumed that the risk matrices and criteria of the parties themselves are used alongside the shared decision-framework.
Drawing implementation agenda (Figure E.9)	R6-S46 Rule: RWS must request budget from the Ministry of Infrastructure and Water Management if BRZO-companies or ProRail report need for water storage areas. or Strategy: RWS is not responsible for financing road adaptation measures.	When returning to the interview data, the following findings came forward: *"One could pose that the Port is responsible for payments for dikes for instance, but just like companies coming to an agreement among themselves in an emergency plan, I can imagine that the Port will not take all the entire responsibility for this. That is also not its duty, Safety Regions will also play an important role in this."* *"We have to come up with solutions on the grounds of others in a system of another owner and you can think of that together but it must also be implemented. Then it becomes a difficult discussions of who will pay for it. We will then look very quickly at the national government, who does not yet have an answer ready or a policy ready to deal with it."* Based on the data, it is assumed that there is an overall perception that the funding of climate adaptation measures is something that is being negotiated, with the perception that often times, it is on a national level that financial aid can be offered. It is not the responsibility of a single actor.

4.3.2 Network metrics

Density

Network density describes the number of actual connections in a network as a share of the number of potential connections in a network. In the original INDs, the connections exist between the actors (attributes) and the outcomes in the network. Density can therefore be calculated by considering the attributes only, and by considering both attributes and outcomes. Considering attributes only gives a better overview of how the institutions link different decision-makers. Therefore, it provides more insights than when both the attributes and outcomes are considered in the calculation.

By taking the average of the densities of all the original INDs, it was shown that the overall density of the network with the 15 attributes is 0.292 (Appendix F). A very low density implies that there is diversity in the practices of actors in a network and little information exchange. The isolated research efforts, and the information-sharing to the Port of Rotterdam as the organizer and the actor that takes on a coordinating role during the risk dialogues are possible explanations for this finding.

Centrality

The degree centrality of each actor gives an indication of how many connections it has with the other actors in a network. It is calculated by dividing the number of links per attribute by the average number of links. Based on the centrality, one gets an indication of who the central decision-makers are in the process of climate adaptation.

Based on this calculation, RWS (2.474), ProRail (2.474), the Port of Rotterdam (2.320), the Province of South-Holland (2.010), and the BRZO-companies (1.237) had a centrality higher than 1. These are the parties who are involved in the risk dialogues, and who decide on the measures to implement. Other parties, like the different research institutes conducting knowledge research, are solely connected to the actor requesting a stress test. Thus, one-third of the actors in the network has a high centrality, while the overall network centrality remains low. The advantage of the high centrality of actors is the efficient coordination and clarity on responsibilities, while this also implies that there is only a small group deciding on the course of climate adaptation.

Embeddedness

The structural embeddedness in a network provides insights about the positional power of actors. Some actors activate institutions that guide the behaviour of other actors. Other times, the actions of other actors directly lead to outcomes or sanctions and do not directly impact another actor. The embeddedness of an attribute is calculated by looking at the number of links it has with other attributes, and dividing that number with the number of total links the attribute has (so the links with the outcomes are included). Attributes with an embeddedness of 0 are not nested between other attributes, while an embeddedness of 1 shows that the attributes are always linked to other attributes only.

According to the INDs, there are four attributes with an embeddedness higher than 0.50, namely: the Port of Rotterdam (0.933), the Ministry of Infrastructure and Water Management (0.800), the Municipality of Rotterdam (0.800), and the BRZO-companies (0.625). Given the embeddedness of the individual attributes, the average embeddedness is 0.520. The Port of Rotterdam has a highly nested position in a network, so that this actor has a coordinating role during the risk dialogues. This implies that the information spread in the network mainly happens through this actor. Accountability is therefore crucial to ensure that all the topics that parties think are of big concern are discussed during such dialogues.

4.3.3 Linking INDs

Linking INDs based on the phases of climate adaptation

The four INDs which are drawn are part of the three phases of the Delta Plan on Spatial Adaptation: knowledge gathering, conducting risk dialogues, and drawing an implementation agenda. The arenas are therefore linked chronically, as shown in Figure 18. The knowledge gathering serves as input for the risk dialogue. The outcomes of the risk dialogue are then translated into the efforts for drawing up an implementation agenda.

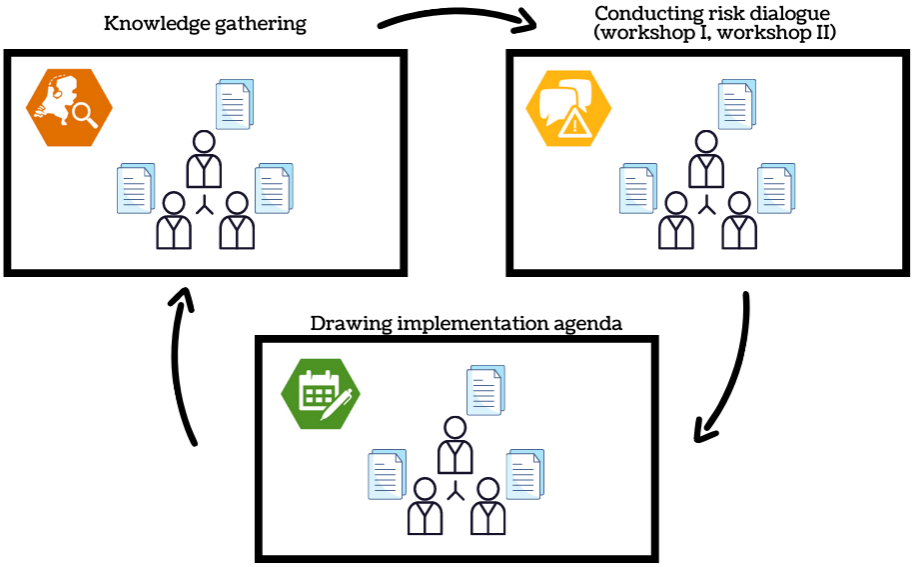


Figure 18: links between the INDs based on the phases of climate adaptation in the Netherlands.

Linking INDs based on outcomes

Figure 19 shows the links between the different INDs through several outcomes. In the knowledge gathering, the various forms of research about the vulnerabilities for infrastructures form the perception of the risks involved for infrastructures. This then affects the acceptable risks which are incorporated in the shared decision-framework or other risk matrices. The frameworks being used again impact the selection of measures, and the budget necessary to realize them. The cost-effectiveness of the measures is an important part within the risk assessment. From the interviews, it became clear that adaptation measures with a long lead time, investments with a long life time, and potentially a large delay before the measures are actually implemented are more likely to be pushed further away in the future. The risk of implementing many “quick-wins”, or smaller projects, is that they might not be effective for the network as a whole.

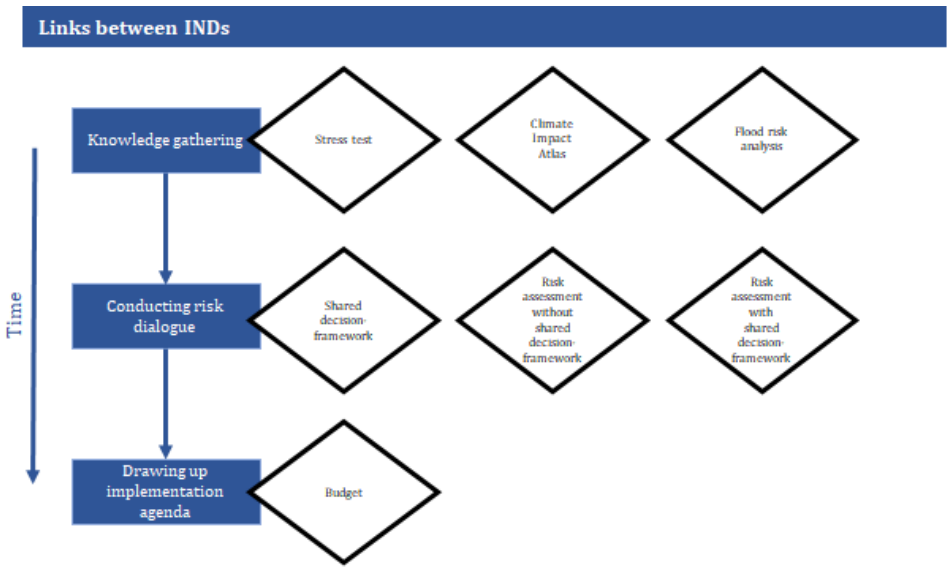


Figure 19: links between INDs based on outcomes,

4.4 Recommendations for better climate adaptation efforts

In this section, the insights from the INA of climate adaptation of transport infrastructures are translated into policy recommendations for the phases of climate adaptation in the Netherlands. This will be done by looking at each three types of analysis of the network: the institutional conflicts, the network metrics and their implications, and the linkage of the INDs.

Addressing institutional conflicts

From the original INDs, two types of institutional conflicts were found which should be addressed from a policy perspective. The first conflict was related to the differences in the criteria and frameworks that actor use to assess the risks for their own infrastructure. Transport infrastructures differ from each other on many different characteristics. Any transport infrastructure has its own limits as to the passengers or cargo that it can carry under different climatic conditions (Profillidis & Botzoris, 2019). The different building elements, economic, and social significance for the environment they are situated in make it that for climate adaptation, there is no single set of norms or rules to which the infrastructures must comply to. The acceptability of climatic impacts and the urgency of adaptation measures are subjects that infrastructure owners and users negotiate about during the risk dialogues. The input to these dialogues are the stress tests and other forms of research resulting from the knowledge gathering phase. During the risk dialogue of the Port of Rotterdam, a shared decision-framework is constructed based on different economic, societal, and environmental consequences that actors report on. The construct therefore functions as a common framework that actors may use in the risk assessment. However, actors have risk matrices themselves that they may use to determine the acceptability of risks. This can cause lengthy negotiations about the order size and the relevant KPIs of the economic, societal, and environmental consequences of climatic impacts. I therefore recommend that the *construction of a common framework becomes a fixed part of the risk dialogues*. This framework will contain KPIs that depict acceptable order sizes of economic, societal, and environmental consequences on the short- and long-term for each climatic hazard as defined the NAS (Table 1). Through a shared decision-framework, a common understanding is created of what objectives actors wish to achieve, and what order sizes of impacts they wish to prevent with adaptation measures.

The second conflict was related to the financial responsibilities for climate adaptation. While officially, companies and citizens are responsible for the risks of water hazards in outer-dike areas, the financial responsibilities of actors in climate adaptation are ambiguous and not defined when infrastructures cross each other. The risks that one infrastructure owner perceives, may only be mitigated through adaptation measures on the other infrastructure, but it is not clear how the measures ought to be financed. Based on this finding, I recommend that the Ministry of Infrastructure and Water Management, who is the responsible ministry for the climate adaptation policies, *supports the progress of the risk dialogues through formal clarification and division of the financial responsibilities on different levels*. This clarification also includes information on the availability of financial sources on national, regional, and local levels depending on the order size of the hazards.

Addressing institutional network structure

The network structure was studied according to three metrics: density, centrality, and structural embeddedness. Table 14 shows the policy implications for the findings of the network calculations.

Table 14: the policy recommendations based on each network metric for this case study.

Transforming network metrics for better climate adaptation			
Network metric	**INA findings**	**Implications**	**Policy implications**
Density	The overall density is 0.292, which is very low. This average was calculated by taking the average of the densities of all the INDs.	A low density implies that there is diversity in the practices of the actors in a network, but also that there is limited spread of information.	Regarding the low density from a policy perspective for climate adaptation, I recommend the following points: - Infrastructure owners need to collaborate on research about the impacts of infrastructure failure on other infrastructures in terms of economic, societal, and environmental damage, and change in occupancy rates on the infrastructures. At the moment, there are no common KPIs which relate to these interdependencies between infrastructures. - Conducting risk dialogues while making the stress tests is an approach which gives climate adaptation a more adaptive and collaborative character. This implies that actors already start risk dialogues while the stress tests are still being constructed. This makes it easier to tweak the stress tests based on the risk perceptions of other infrastructure owners. - A wider range of actors beyond the area directly connected to the Port should be invited to the workshops. The Province of South-Holland for instance was invited to the dialogue, but did not give input about the risks

			that the provincial roads neighbouring the Port of Rotterdam may face. In this respect, more attention should be payed to the supply chains served by the infrastructures, which junctures are critical in case of failure, and who is impacted or may solve this failure. Actors who are invited might also recommend inviting other stakeholders.
Centrality	33% of the attributes has a centrality higher than 1. Overall, the centrality is low, but for a few actors, there is a high centrality in the network.	A network with low centrality, meaning that only one of few actors are highly central, is not robust to removal of this actor. For instance, in this case, if the Port of Rotterdam would not coordinate the risk dialogues, it might become harder to come to an agreement. Low centrality may also imply inefficiency.	To address the low centrality in general, and the high centrality of several actors from a policy perspective for climate adaptation, I recommend the following points: - Having a central actor who oversees the negotiation about the risk dialogues should be used to formulate a common risk assessment framework during risk dialogues. If actors solely use their own risk matrices, the focus of the negotiations may remain on finding a common ground on the criteria and their corresponding acceptable order sizes for the risk assessment. This slows down the decision-making process.
Embeddedness	The average embeddedness is 0.52. Four attributes had a relatively high embeddedness (>0.50), while one attribute was not nested in the network at all.	High embeddedness in a network indicates that actors and their actions are linked to a high extent. On one hand this shows that responsibilities are shared, on the other hand this may cause inefficiency.	To address the findings on the structural embeddedness from a policy perspective, I recommend the following point: - Having one party or few parties who keep the overview of all the viewpoints of actors is beneficial, on the condition that there is control and limits to the power of these decision-makers. During risk dialogues, participants may formally point out impacts that have not been sufficiently highlighted but which are crucial to the functioning of infrastructures surrounding the Port.

Linking INDs

The different INDs were linked through multiple outcomes. The knowledge gathering phase resulted in climate impact atlases, stress tests and a flood risk analysis, which were used to determine the framework for the assessment of the severity of risks and the urgency of climate adaptation measures. However, the focus on this case was on floods only, while impacts such as drought and heat were not shared in the risk dialogues. There are several reasons one can give for this. First of all,

Figure E.2 shows that while the indicators for flood severity and water hazards are well developed, this is not the case for drought and heat. Meaning, that while the impact on water hazards and floods is evident, this is not the case for drought and heat. Secondly, the private companies at the harbour are obliged to report how they cope with water hazards as a firm, while there are few formal institutions on drought and heat impacts. Therefore, I recommend that *actors involved in climate adaptation surrounding the Port of Rotterdam re-evaluate the consequences of climatic impacts by incorporating drought and heat explicitly in the knowledge research, risk dialogue, and implementation agenda of the Port.*

5. Conclusion

This chapter gives a summary of the contributions of this thesis. First, the research questions which had been formulated for this research will be answered (section 5.1). Next, the scientific contribution to the method used in this research, Institutional Network Analysis (INA), will be highlighted (section 5.2). Lastly, the limitations of the research, along with recommendation for future research are provided (section 5.3).

5.1 Contribution to understanding institutional connections and dependencies in climate adaptation

Transport infrastructures that connect ports to the hinterland are important enablers of economic growth and development in the region. Their function also makes them particularly vulnerable to the impacts of climate change, such as heavy rainfall, floods, increased drought, and heat. Climate hazards may lead to substantial economic costs associated with infrastructure replacement and repair, and numerous broader implications, given the concentration of populations, assets and services associated with ports. The risks associated with climate change made governments on all scales increasingly aware of the fact that there is a level of unavoidable climate change that society must cope with, regardless of the future emission trajectories. Therefore, infrastructure owners and governments in different levels are engaging in climate adaptation to adapt transport infrastructures to actual or expected climatic hazards.

Disruptions due to climatic hazards in one infrastructure may propagate to the other infrastructures, resulting in network-wide failure. It is thus important to prevent unsystematic, individualistic and pluralistic climate adaptation efforts. The behaviour of the actors involved in climate adaptation is guided by rules, norms, and strategies, referred to as institutions. Existing research on the institutional dimension of climate adaptation has exclusively focussed on studying institutions in isolation from each other. Researchers tried to understand whether existing institutions allowed and encouraged actors to develop and realize adaptation strategies, and as a result, enhance the adaptive capacity of society. However, interdependencies and connections between institutions that guide actors were not studied for climate adaptation. Furthermore, there was no method that could systematically map these connections between institutions.

The goal of this research was therefore to systematically track the connectivity and interdependencies between institutions in climate adaptation of transport infrastructures around ports for two purposes. First, to give formulate policy recommendations to governments, infrastructure owners, and the private sector to improve current climate adaptation practices for transport infrastructures. Second, to track the relations between institutions systematically with a method devoted to identifying and mapping them. Therefore, the following main research question was formulated:

How can institutional interactions be studied for climate adaptation of interdependent transport infrastructures surrounding port areas?

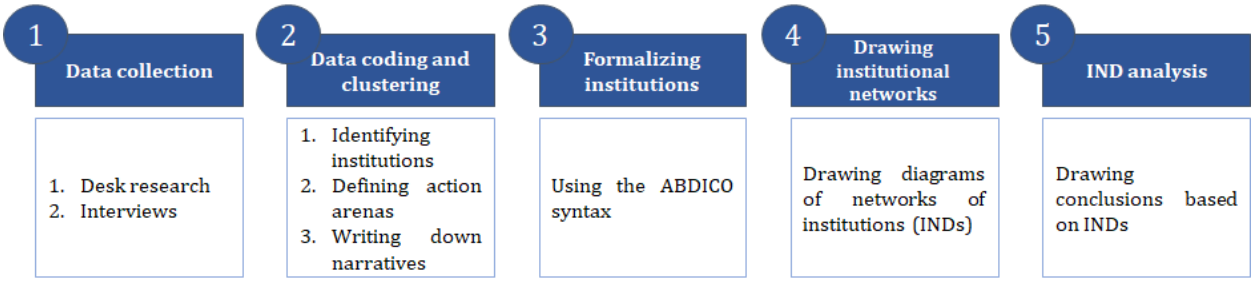
For this purpose, the four sub-questions which were formulated will be answered first.

1. How can the relations between institutions be systematically identified?

The first sub-question aimed at formulating a methodology to look at the connections between institutions. Which institution activates another institution, and what are the corresponding outcomes? The goal was to understand these relations by systematically mapping them.

Therefore, a conceptual framework was constructed which consisted of three building blocks. First, the Grammar of Institutions (ABDICO syntax) was used to formalize rules, norms, and strategies, as institutional statements (Crawford and Ostrom, 1995). An institutional statement is a "shared linguistic constraint or opportunity that prescribes, permits, or advises actions or outcomes for actors" (Crawford & Ostrom, 1995, p. 583). Second, the Institutional Analysis and Development (IAD) framework was used to show the environment in which the influence of institutions leads to certain outcomes (Ostrom, 2011). This environment was referred to as an action arena, in which actors interact with each other within so-called action situations, which in the case of climate adaptation, is a space where the actors work towards problem-solving. Third, the social network paradigm was used as a foundation to connect the institutional statements within action arenas.

This led to the formulation of five steps for the Institutional Analysis and Development (INA) method.



The first step of data collection was conducted through desk research and 16 semi-structured interviews. The data then needed to be coded and clustered. Coding is a method used to analyse data by identifying themes, or 'codes', that appear in the qualitative data, and then assigning sections of the data to these codes. The coding of the data was conducted in Atlas.ti. The codes were then clustered and assigned to one of the three phases of climate adaptation, namely: knowledge gathering, conducting risk dialogues, and drawing up an implementation agenda. These three phases were also used to define the action arenas.

For the formalization of the institutions, the components of the ABDICO syntax were used to formulate institutional statements. After the institutional statements are formulated, Institutional Network Diagrams (INDs) were constructed. An IND shows the links between the institutions for a particular action arena. The links between attributes are made through the dependencies that exist between the objectives, and the conditions of institutional statements. By drawing all the INDs for climate adaptation, one was able to see which institutions make up every action arena, and how they guide actors towards outcomes. The steps to drawing an IND are shown in Table 10.

There are several ways in which the connections between institutional statements can be studied in more depth. The first way is by paying attention to the presence of institutional conflicts. An institutional conflict is a situation where two or more institutions with different outcomes guide actor behaviour.

Next, different network metrics can be calculated that give more information on the position of actors, the spread of information, and the involvement of actors in a network. The metrics in this research were: density, degree centrality, and structural embeddedness. Furthermore, the INDs can be linked to each other based on the more or less chronological order of the three phases of climate adaptation in the Netherlands, or through the outcomes shown within the INDs. Connecting the INDs allows researchers to study the performance of the whole system of climate adaptation, rather than only paying attention to institutional statements within one particular IND or action arena.

Lastly, the structure of the INDs enables the construction of aggregated formal charts (section 3.5), which show based on what institutions actors exert influence on each other.

2. Who are the actors involved in the climate adaptation of transport infrastructures?

As a case for the application of the INA, the transport infrastructures connected to the Port of Rotterdam were considered, which were roads, railways, waterways, and pipelines. The Rotterdam region was identified as one of the "hotspots" in the Netherlands which is particularly vulnerable to the impacts of climate change (Westerhoff et al., 2010). This was due to the presence of the Port of Rotterdam, and the important economic benefits it generates for the region and the Dutch economy. The Port of Rotterdam is situated near the sea, and at the same time lies in proximity of urban areas. Moreover, there is a multimodal transport infrastructure to and from its hinterland, which is particularly vulnerable to extreme weather events (Ruiten et al., 2016).

The framework on climate adaptation in the Netherlands consists of two parts: the National Adaptation Strategy (NAS) (subsection 2.1.1) and the Delta programme (subsection 2.1.2). The NAS is an overarching strategy on a national level, and aims to raise awareness on all possible impacts of climate change. The Delta programme followed from the NAS, and is a cooperative effort between all layers of the Dutch government. Its focus is mainly on the development of spatial measures for problems on fresh water conservation, water management safety, and spatial adaptation (Ministry of Infrastructure and Water Management, 2018). The ambition in the Delta Plan on Spatial Adaptation is that t*he Netherlands is water-robust and climate-resistant in 2050* (Delta Programme Commissioner, 2020c). This implies that spatial measures need to be developed to be able to cope with the four overarching categories of climate hazards. These are: waterlogging, heat stress, drought, and sea-level rises (Kennisportaal Ruimtelijke Adaptatie, 2020a). In order to realize this, governments on national, regional, and local levels are currently following the three ambitions in the Delta Plan on Spatial Adaptation, namely: knowledge gathering, conducting risk dialogues, and drawing up an implementation agenda (Figure 2).

One area where infrastructures come together and cross each other is the Botlek and Vondelingenplaat area. The Port of Rotterdam is not officially involved in the Delta Plan on Spatial Adaptation, but the Delta Plan on Water Safety. However, the Ports' approach to climate adaptation consists of phases that correspond to the three general phases of climate adaptation in the Netherlands. Moreover, the infrastructure owners whose infrastructures are connected to the Port all work according to the Delta Plan of Spatial Adaptation. The involvement of actors in this area be understood in two ways. First, it is possible to merely look at the different responsibilities of parties who are present in the outer-dike area, as shown below (Kennisportaal Ruimtelijke Adaptatie, 2018).

The structure within the improved INDs provide more information on the responsibilities and involvement of the actors. The INDs showed that for the purpose of knowledge research, infrastructure owners conduct stress tests according to the Delta Plan on Spatial Adaptation. In this construction, each party works individually and does not collaborate with other actors in research. The climatic impacts from the stress test are the same as outlined in the NAS and the Delta Programme, and include water hazards, floods, drought, and heat. The Port of Rotterdam also initiates its own research efforts for the Ports' infrastructure, but for floods only. After the results of the research are available, the Port of Rotterdam reports its findings to infrastructure owners that it invites to risk dialogues. These include RWS, ProRail, and BRZO-companies who need to comply to external water safety standards on their terrain. In the risk dialogues, the Port of Rotterdam takes a coordinating role, receives input from all the parties about their findings and associated consequences, and develops a shared decision-framework for the risk assessment. Based on this shared framework and the risk matrices of infrastructure owners themselves, a selection can be made of the necessary measures to implement. In the INDs, these interactions have been summarized through written documents (Appendix A) and interview transcripts.

3. How can climate adaptation efforts be assessed by looking at institutional interactions?

The analysis of the INDs has been done in several ways. First, institutional conflicts were identified. Institutional conflicts are situations where two or more institutions with different outcomes guide actor behaviour. It is important to understand which institution are followed in that case and under what circumstances.

In the case of the Port of Rotterdam, two instances of institutional conflicts were identified in the original INDs. The first conflict was related to the different sets of criteria and frameworks for the risk assessment that actors use. The second conflict was related to the ambiguity in the responsibilities in financing climate adaptation measures.

Next, the original INDs were analysed by considering three network metrics. The first metric was density. The overall density in the network was 0.292, which was very low. A low density implies that there is diversity in the practices of actors in a network, and a limited spread of information. The second metric was centrality. Given all the original INDs and the 15 actors involved in them, one-third of the actors in the network had a centrality higher than 1. A high centrality implies that the network is not robust to the removal of this actor. For instance, in this case, if the Port of Rotterdam would not coordinate the risk dialogues, it might become more difficult for infrastructure owners, government agencies, and private companies to come to an agreement on the most urgent risks. Lastly, the structural embeddedness was calculated for the individual actors, or attributes. Structural embeddedness gives information on the network involvement of different actors. When an actor has a high embeddedness and is therefore nested between various actors in the network, it becomes easier to spread information for him. High embeddedness therefore also implies that an actor can be held accountable to a high extent and that there is more social control than situations when the embeddedness of an actor is low. The average embeddedness was 0.520. Four actors, in this case, the Port of Rotterdam, and the infrastructure owners who were involved, had a relatively high embeddedness.

Lastly, the original INDs were be linked to get a better understanding of dependencies between outcomes between the INDs and understanding how the INDs are linked as a whole. The linkages showed that the results of the research from the knowledge gathering determine the risk perception of actors. The risk perception then again impacts give substance to the decision-framework constructed for the risk assessment, and how much budget will be required to take the necessary measures. The focus in the case of the Port of Rotterdam was on floods only, which causes the focus of the whole climate adaptation progress to remain on this climatic impact only in all the INDs.

Due to time constraints in the research, the analysis and construction of aggregated formal charts (section 3.5) was not conducted for the improved INDs. However, since the institutional statements largely overlap, the results from the analyses still apply to the improved INDs as well.

4. How can climate adaptation efforts be improved based on an assessment of institutional interactions?

Based on the analyses, the following recommendations are formulated for the actors in the Botlek and Vondelingenplaat area.

Addressing Institutional Conflicts

1. It is recommended to make the *construction of a common framework a fixed part of the risk dialogues*. This framework will contain KPIs that depict acceptable order sizes of economic, societal, and environmental consequences on the short- and long-term for each climatic hazard as defined the NAS (Table 1). Through a shared decision-framework, a common understanding is created of what objectives actors wish to achieve, and what order sizes of impacts they wish to prevent with adaptation measures. Not only is this beneficial for the actors who participated in the risk dialogue, but other actors can also access this framework when it is publicly available.

2. It is recommended that the Ministry of Infrastructure and Water Management *supports the progress of the risk dialogues through formal clarification and division of the financial responsibilities in climate adaptation*. This clarification also includes information on the availability of financial sources on national, regional, and local levels depending on the order size of the hazards found during the risk dialogues.

Addressing the findings of the network metrics

1. Infrastructure owners need to *collaborate on research about the impacts of infrastructure failure on other infrastructures in terms of economic, societal, and environmental damage, and change in occupancy rates on the infrastructures*. At the moment, there are no common KPIs which relate to these interdependencies between infrastructures.

2. *Conducting risk dialogues while making the stress tests is an approach which gives climate adaptation a more adaptive and collaborative character*. This implies that actors already start risk dialogues while the stress tests are still being constructed. This makes it easier to tweak the stress tests based on the risk perceptions of other infrastructure owners.

3. *A wider range of actors beyond the area directly connected to the Port should be invited to the workshops*. The Province of South-Holland for instance was invited to the dialogue, but did not give input about the risks that the provincial roads neighbouring the Port of Rotterdam may face. In this respect, more attention should be payed to the entire supply chains served by the infrastructures, which junctures are critical in case of failure, and who is impacted or may solve this failure.

Addressing the findings of the linking of INDs

Actors involved in climate adaptation surrounding the Port of Rotterdam should *re-evaluate the consequences of climatic impacts by incorporating drought and heat explicitly in the knowledge research, risk dialogue, and implementation agenda for the Port.*

Given the answers to the sub-questions, the main research question can now be answered.

How do institutional interactions influence climate adaptation of interdependent transport infrastructures surrounding port areas?

Disruptions due to climatic impacts in one infrastructure may propagate to the other infrastructures, resulting in network-wide failure. At the same time, these infrastructures are situated in an area with multiple ownerships. It is therefore important that infrastructure owners prevent unsystematic, individualistic and pluralistic climate adaptation efforts. The behaviour of the actors involved in climate adaptation is guided by rules, norms, and strategies, referred to as institutions. Institutions are not isolated from each other however, but are connected to each other and interdependent. To understand how the different infrastructure owners around ports interact, a network perspective can be taken where the links between actors in different decision-spaces are defined by the institutions that connect them. In this way, the institutions enrich the social network theory, since the links conventional networks are not defined by institutions. At the same time, a network perspective allows for new ways of studying these institutions, namely through finding institutional conflicts and calculating network performance metrics.

5.2 Scientific contribution to the Institutional Network Analysis (INA) method

The main objective of this research was to apply a method on the case of the Port of Rotterdam to better understand the connections and interdependencies between institutions, as well as the complexity in climate adaptation of transport infrastructures. In this research, the Institutional Network Analysis (INA) was used to visualize the relations between institutions from a network-perspective. This research contributed to several steps of this method.

The first contribution was related to the formalization of institutions (INA step 2). In the original series of steps, the institutions were formalized according to the ADICO syntax. In this research, the object component (Siddiki et al., 2011) was also included in the formalization process. For the formalization of institutions from written documents, several authors had given steps to guide the researcher in this task (section 3.3.1). However, there was no guide which explained how this could be done for interview transcripts. The format of interview transcripts is different than that of laws, regulations, and policy documents. Therefore I proposed the following steps to help future researchers in the formalization of the institutions. I drew from the examples of Watkins & Westphal (2016) and my own experiences in deriving institutional statements from the semi-structured interview transcripts. The full descriptions of the steps and their application on a few quotations from an interview transcript can be found in section 3.3.2.

Step	
1.	Identify sentences as initial units of observations.
2.	Mark the verbs in case they have an action (the "what" in a sentence) along with them in each sentence. Also mark the action.
	If the action is a pronoun, look at surrounding sentences and write down the noun that the pronoun is referring to.
	If there is no action along with the verb, you do not have a statement, but you have identified a piece of information, a description in your case.
3.	Mark the subject as well in each sentence. Write down the attribute and aim from these marks. If the subject is a pronoun, try to specify the noun it is referring to by looking at surrounding sentences.
	If the subject is an animate noun and conducts the action, label this subject as the attribute [A]. Label the action they are conducting as the aim [I].
	If the subject is inanimate noun and conducts the action, this sentence might be providing information for another institutional statement, as an outcome or condition for example. It is also possible that you have not found an institutional statement, but some information regarding your case.
4.	Mark the conditions under which the actions are conducted in each sentence.
5.	Mark the objects in the units of observations.
6.	Add, further specify, or rewrite components in each unit of analysis by looking at information in the surrounding sentences (the other units of analysis).
7.	Determine the deontic for every statement so far.
8.	Determine the presence of any tangible or emotional sanctions in each unit of analysis.
9.	Code all units of observation as rules, norms, or strategies.

The second set of contributions relate to the construction of the INDs. The *object* component of the ABDICO syntax (Siddiki et al., 2011) was added to the INDs (Figure 10). Adding the *object* component to the diagrams allows one to better understand how one institutional statement influences another institutional statement. Essentially, attributes (actors) are triggered to conduct the aim (action) of an institutional statement through the conditions. Whether conditions actually trigger the conduct of an institutional statement, is shown to be dependent on properties of the object connected to it. This relation is shown through the dotted arrow between the object of one institutional statement, and the condition(s) of another institutional statement. Such a relation implies that the actor conducting the first institutional statement has a certain influence over the behaviour of the other actor.

Another addition to the INDs was including the different levels (operational, collective-choice, and constitutional) at which objects influence the conditions (Figure 11). As explained before, objects are the inanimate or animate part of a statement that receive the action. They may therefore also exist on higher levels in other action arenas, and exert influence over the institutional statements in the operational INDs. This influence is shown by connecting objects on a collective-choice level and constitutional level with dotted arrows to the conditions(s). Including the different levels allows one to improve the current structure of the formal charts (section 3.5).

Lastly, other elements used to visualize the institutional statements were altered. The main purpose for this was to make the building blocks of each institutional statement more homogeneous.

5.3 Limitations and recommendations for future research

In this section, limitations in each of the steps of the INA method are outlined. Every subsection summarizes the recommendations for every step of the INA method. Then, a more detailed explanation behind every recommendation is provided. There are also several recommendations provided for climate adaptation which do not directly relate to the INA method (subsection 5.3.6).

5.3.1 Data collection

Recommendation
In case of a scarcity of institutions, attend risk dialogues if possible, so that the risk assessment is more transparent to the researcher and institutions can be drawn on first-hand experiences.

Few institutions on the course of risk dialogues and implementing adaptation measures

The data for this research was collected through desk research, and semi-structured interviews. The data collection focussed on the three general stages of climate adaptation in the Netherlands: knowledge gathering, conducting risk dialogues, and drawing implementation agendas. However, during the data collection, it became clear that while these different stages have been defined in strategies for climate adaptation in the Netherlands, the majority of the national infrastructure owners were still in the phase of gathering knowledge about the impacts of climate change. Furthermore, the knowledge gathering was conducted in parallel, which implied that not all national infrastructure owners, local governments, and private parties were finished with the stress tests or other research they were conducting when this research was conducted.

This was why there were fewer institutions on how risk dialogues were conducted, and how the outcomes of these dialogues were translated to implementation agendas. This is also explained by the fact that not all actors have experienced conducting a risk dialogue in the first place. Therefore, during the interviews, actors would answer that they would 'negotiate' and try to 'come to an agreement'.

However, they did not exactly mention *how*, so according to which institutions, they attempted to do this. Institutions for risk dialogues and drawing up an implementation agenda were also more scarce because risk dialogues can be conducted in different formats. The format may be local, as a dialogue with citizens in a neighbourhood, but also national, as a series of workshops with different national infrastructure owners. While this gives stakeholders the flexibility to adapt the information provision or the content of a dialogue to a specific context or situation, it makes it more difficult to collect data because it is not clear according to which institutions actors act. It is recommended that future researchers attend risk dialogues if this is possible, so that institutions can immediately be drawn from the dialogues themselves.

Identifying institutions in use

During the semi-structured interviews, actors not only gave descriptions of the institutions in use, but also described institutions they *wished* were followed in reality. They would describe their ideal situation or outcomes for instance. This was interesting for understanding the narratives and objectives that different stakeholders had in mind. An example was the tension between economic and societal objectives of different private and public actors. However, the researcher must be able to distinguish the actual institutional statements in practice, and institutional statements that respondents wished were followed in practice. The language used by the respondents in this case is particularly important. For example, when an actor describes a form of cooperation or negotiation with other stakeholders, is he describing a desired situation, or the reality of how they work together in practice? The researcher may also ask the respondent for confirmation afterwards during a follow-up interview.

Conducting the interviews

The main purpose of conducting the interviews was to understand according to which institutions actors act in their climate adaptation efforts. However, during several interviews, the focus would shift from the institutions that guide climate adaptation behaviour, to climatic risks that actors perceived to be of serious, and motivations for engaging in climate adaptation in the first place. If interviews were conducted with the purpose of asking about the institutions that actors followed when interacting with each other, the data would have been more valuable. Moreover, the interviews had to be conducted online or through the phone due to the coronavirus outbreak. If the interviews were conducted in person, it would have been possible to observe someone's body language, expressions, and emotions when discussing the topic of climate adaptation. This would have helped in asking follow-up questions during the interview, and in writing down the narratives.

5.3.2 Data coding and clustering

Recommendation

Conduct the data coding and clustering in teams so that the bias of an individual researcher is overcome and comparisons are made between narratives of individual researchers.

Bias of coding and clustering individually

After collecting the data, the data was iteratively clustered and coded to find common themes for narratives and the construction of institutional statements. For the coding, an initial list of topics was made by the researcher to make the clustering of the data more straightforward. However, one must keep the bias in mind that the researcher might have incorporated in the coding and clustering. This bias might for instance relate to certain problems that the researcher perceived after hearing different respondents mention them during interviews.

These problems may then dominate during the coding and clustering process so that these are highlighted in particular. Having a team or several researchers doing the coding and clustering, helps to emphasize different topics or problems brought forward by the respondents, and helps in comparing the narratives.

5.3.3 Formalizing institutions

Recommendations

1. More research is needed to guide researchers in deriving institutions from interview transcripts. Adding additional steps or modifying existing steps provided in this research supports researchers to safeguard important information from interview data when using the ADICO-syntax.
2. Institutions are multi-interpretable. Just like during the data coding and clustering, having teams for formalizing the institutions helps to compare different interpretations of the institutions and overcome individual bias.

Formalizing information from interview transcripts

The data in this research consisted of written documents and interview transcripts. While different studies have outlined steps for deriving institutional statements from written documents, this process is less straightforward and developed for interview data. This research outlined a series of steps for deriving institutions from interview data, but it is necessary to conduct additional research to validate these steps. This helps to improve the steps by modifying them or by constructing additional steps.

Bias of individual formalization of institutions

In this research, one person formalized all the data and wrote down the institutional statements. In this formalization process, individual bias may be overcome by having a team that conducts the formalization. This way, the different interpretations of the statements can be exchanged.

5.3.4 Institutional Network Diagrams (IND)

Recommendations

1. Institutional Network Diagrams (INDs) may be drawn for the same action situation several times to show how the interactions between actors changed over time. This also allows the researcher to give explanations for why the interactions in today's action arena are shaped the way they are.
2. Future researchers can improve the construction of the INDs by adding elements that explicitly show conflicts between the interests of actors in an action arena.

Using the diagrams to depict institutional change

The INDs show how institutions relate to each other in a specific action arena. On their own, the diagrams do not show the dynamics of institutions, or how institutions change over time. Institutions change due to leaning experiences of actors who interact with each other. In order to show the changes in the interactions between the actors over time, several diagrams may be made to show the same decision-making situation at different points in time. These diagrams allows the researcher to understand how the interactions changed over time, and provide the researcher with possible explanations for why interactions are shaped as they are now.

Using the INDs diagrams to depict conflicts in the interests of actors

Currently, the INDs show how institutional statements have objects, of which the properties can activate other institutional statements. These objects can be any animate or inanimate part of a statement that receives an action. Various economic, societal, and environmental objectives may therefore also be objects in institutional statements. In this research, there were no dedicated elements in the INDs which visualised these objectives. Future researchers can therefore work on incorporating these elements and showing conflicts between the different attributes in an IND which can result from conflicting objectives or interests.

5.3.5 IND analysis

Recommendations
1. The IND analysis may be used as a basis for agent-based modelling or other modelling disciplines to show the dynamics within and between the three phases of climate adaptation.
2. The network analysis may be implemented in a programming software so that the network metrics can be determined automatically.

Showing the dynamics within and between the three phases of climate adaptation

During the interviews, one of the most frequently mentioned characteristics of climate adaptation was that knowledge gathering, conducting risk dialogues, and drawing an implementation agenda are all highly iterative processes. The element of learning is very important since climate adaptation is a relatively new policy-making field. Learning does not only relate to learning about the effectiveness of policies, or the effectiveness of different configurations of risk dialogues, but also to learning about the objectives and dilemmas of other actors involved. While the INDs shed light on the position of actors and their interactions, they do not explicitly reflect the institutional dynamics over time. Climate adaptation is therefore an interesting topic to explore with different modelling tools. Agent-based modelling for instance is a tool which has frequently been used to model socio-technical systems (Ghorbani, Ligtvoet, Nikolic & Dijkema, 2010). In these systems, social elements such as actors develop, sustain, and depend on technical systems, like infrastructures (Nikolic & Ghorbani, 2011). Agent-based modelling is particularly suitable for understanding the dynamics of climate adaptation as it shows the feedback mechanisms between changes in climate adaptation policies and the changes in stakeholders' goals and perceptions.

The use of software for calculations of network metrics

In this research, apart from the process of drawing the diagrams, an additional analysis was carried out by calculating network metrics for every actor in the network. These calculations were done manually by observing the connection that actors have with each other. In order to reduce the calculation time, the network analysis may be implemented in a programming software so that the network metrics can be determined automatically.

5.3.6 Other recommendations for future research in climate adaptation

Recommendations
1. Focus on finding common Key Performance Indicators (KPIs) based on the potential impacts of drought and heat, to support decision-makers.
2. Existing knowledge gathering puts little emphasis on cascading effects of infrastructures on each other. Future researchers must focus on providing insight in these interdependencies by detecting the impact of one infrastructure on the functioning of the other infrastructure.

3. Conduct a comparative study between ports in the Netherlands and abroad to identify strong and weak points in climate adaptation approaches.
4. Future researchers may focus on factors which play a critical role in enabling climate change adaptation on a local level as opposed to the national level.

Focus on drought and heat

This research aimed to look at climate adaptation for four impacts of climate change included in climate adaptation strategies in the Netherlands: water hazards, floods, drought, and heat. From the interviews and publicly available data, it became evident that many actors have little information on the impacts of drought and heat. For water hazards and floods, the economic and societal impacts were often known, and it was clear how to quantify the impacts due to the long history the Netherlands has had with water hazards and floods. In stress tests, the number of consequent days with high temperatures (>25 °C) were used to depict heat, or changes in ground water levels were used to depict drought. However, actors did not know how this information could be translated to the infrastructural impacts. In the end, this scarcity of information put the focus in the analysis on water hazards and floods. It is necessary to conduct more research on finding economic, social, and environmental KPIs to assess the impacts of drought and heat on infrastructures.

Interdependencies between infrastructures

In this research, the institutional analysis of climate adaptation focussed on different transport infrastructures. While the analysis showed how the infrastructure owners, government agencies, and other stakeholders interact with each other, there were little institutions found which focus on determining certain cascade effects of the failure of one infrastructure on the other. The interdependencies between infrastructures, and how failure of one infrastructure impacts the other economically, socially, and environmentally, were not studied yet. Future research is needed to understand these consequences.

Comparative studies

This research focussed on climate adaptation for the case surrounding the Port of Rotterdam. However, the approach chosen to tackle water hazards and floods in this area is not necessarily the same working style in other areas or for other ports in the Netherlands. A comparative study between different ports in the Netherlands would be fruitful to understand the strong and weak points of distinct climate adaptation approaches.

Factors influencing the success of climate adaptation on local and national levels

A notable finding from the interviews in this study was that climate adaptation seemed to progress more easily on a local level than on a national level. However, the focus on this research was on understanding the structure in which actors interact with each other on a local level only. The diagrams were not used to compare local and national climate adaptation efforts. Future researchers may focus on detecting the factors that enable climate adaptation on different levels, and how they overlap or differ from each other.

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Appendix A: List of reviewed documents on climate adaptation in the Netherlands

The available documents and websites that were reviewed on climate adaptation surrounding the Port of Rotterdam are alphabetically listed by below:

Application for water permits – RWS (2020)
Deltaprogramme report (2020)
Guide on Climate Adaptation ProRail (2019)
Guide on Communicating Water Safety Risks in Outer-Dike areas (2012)
Guide on Conducting Risk Dialogues (2020)
Guide on Integrating Sustainability in MIRT-projects – Themes Energy/CO_2 and Climate Adaptation (Handreiking Verduurzaming MIRT) (2020)
Guide Standardized Stress test Spatial Adaptation (2019)
Climate Adaptation Strategies:

- Adaptation Strategy for Outer-Dike areas – Municipality of Rotterdam & Royal Haskoning DHV (2017)
- 'Programma Adaptieve Delta' – as part of the Climate Adaptation Strategy of the Province of South-Holland (2018)
- 'Rotterdam Weerwoord' – Climate Adaptation Strategy Municipality of Rotterdam (2020)
- Water Safety Report of the Botlek Area (2017)
- 'Weerkrachtig Zuid-Holland' – Climate Adaptation Strategy Province of South-Holland (2018)

Laws and regulations:

- Environmental Conservation Act (2019)
- Major accident Hazards Act (2020)
- Port Security Act (2019)
- Regulation on tasks and meteorology and seismology (2015)
- Safety Regions Act (2020)
- Spatial Planning Act (2018)
- Water Act (2020)

Policies:

- National Adaptation Strategy (2016)
- National Water Plan (2016-2021)

Stress tests:

- Stress test RWS National Road Network (2020)
- Stress test Province of South-Holland (2018)

Appendix B: interview questions

In this section, an overview is provided of the interview question for the semi-structured interviews. They were not strictly guiding the interview, but served as a guide one could refer to during the interview.

List of interview questions

For the interviews, questions were written and grouped according to:

1. The action arena they expected to provide information on. The action arenas fall in one of the three general phases of climate adaptation in the Netherlands: knowledge gathering, conducting risk dialogue, and drawing up an implementation agenda.
2. The level of the institutional statement they would relate to: constitutional, collective-choice, or operational.
3. The class of the institutional statement. This helped assuring that none of the classes of statements dominate, but that there is a balance between the different types of questions and information brough forward during the interviews.

Action Arena: Knowledge gathering **Constitutional Level**
Boundary Statements Are there any binding regulations which oblige parties to gather knowledge for climate adaptation efforts?
Position Statements The Implementation programme for spatial adaptation (NAS) states that the Ministry mainly has a "coordinating role". Can you elaborate on this role? Who decides when to carry out/update a stress test?
Choice Statements Are the stress tests compulsory? Or are there other ways in which climate impacts can be analysed for projects?
Information Statements Are stress tests the leading means of improving the knowledge base on climate adaptation for transport infrastructures? Why is this (not) the case?
Scope Statements When is it required to carry out a stress test? What is used to safeguard the quality of different stress tests? What is used to safeguard the quality of different research for climate change impacts?
Payoff Statements What happens if stress tests are not carried out by parties?
Collective-Choice Level
Boundary Statements Which parties can join knowledge research efforts for transport infrastructures?
Position Statements Governments on different levels carry out stress tests according to the Delta Programme of Spatial Adaptation. Does the ministry also carry out stress tests?
Choice Statements Which means for research is selected?
Information Statements Is it possible for there to be confidentiality problems with data sharing for stress tests? Which data must be used for research? Are parties free to choose what climatic impacts they will focus on?

Scope Statements
Is there a standard for the climatic impacts for transport infrastructures?

Payoff Statements
Who is responsible for guarding the quality of a stress test/research?

Operational Level

Boundary Statements
Which parties usually carry out stress tests or others forms of research?

Position Statements
Why are stress tests made by each infrastructure owners separately?

Choice Statements
Which climatic impacts do parties focus on in stress tests?

Scope Statements
How does one decide whether a stress test needs to be updated/revised?
How are the outcomes of the stress tests mapped by infrastructure owners?

Payoff Statements
Are stress tests/research one-off or are they conducted for separate projects?

Action Arena: Conducting risk dialogue

Constitutional Level

Boundary Statements
On which levels are dialogues about climate change risks to be organised between infrastructure owners?
Who are allowed to participate in the dialogues?

Position Statements
Does the Ministry take a leading role in arranging and coordinating dialogues between actors?

Choice Statements
The directorate-general of climate adaptation develops "policies in the field of climate adaptation". Can you elaborate on this for infrastructures?

Information Statements
Must information on climate change risks be communicated between infrastructure owners?
Is it expected to communicate risks with stakeholders who might not join dialogue (e.g. Port of Rotterdam)?

Scope Statements
How can the results of different stress tests compared to each other?
How are stress tests adapted according to the results of other infrastructure managers?

Payoff Statements
How are the stress tests translated into adaptation efforts?

Collective-Choice Level

Choice Statements
How do you decide which stress test/other knowledge base research to give prevalence to? Because stress tests for example are carried out by different parties (e.g. provinces, municipalities…).

Information Statements
When and where are the results from stress tests/research on infrastructures communicated (e.g. risk dialogues and NAS adaptation dialogues)?

Aggregation Statements
What makes a risk or hazard critical?

Scope Statements
Are impacts of infrastructures on each other determined and discussed?

Payoff Statements
Are the outcomes of the dialogues evaluated?
Who is responsible if risks are not adequately communicated?

Operational Level

Choice Statements
How is it decided which risks are significant? Does this happen based on one stress test only or are findings of different parties compared with each other?

Information Statements
Are there ever conflicts in what parties consider to be the critical problems in infrastructures?
Have you ever experienced communication problems between infrastructure owners in discussing adaptation urgencies or efforts? Why?

Aggregation Statements
How do parties come to an agreement on the risks that are most critical?

Payoff Statements
Are there any follow-ups to these dialogues?

Action Arena: Drawing up implementation agenda

Constitutional Level

Position Statements
Who decides whether infrastructures are robust to climate change or not?

Scope Statements
Does the Ministry monitor how responsibilities for climate adaptation are divided?

Collective-Choice Level

Position statements
How are the responsibilities for climate adaptation on a regional level divided?

Choice Statements
How are climate adaptation plans evaluated?

Information Statements
Do parties have to report on their adaptation efforts to the Ministry? How are these efforts communicated?

Aggregation Statements
Are infrastructure owners allowed to undertake climate adaptation efforts for infrastructures by themselves? Are they supposed to coordinate these efforts with each other?

Scope Statements
Do infrastructure owners have to report on the expected future benefits of climate adaptation efforts?

Payoff Statements
Are there sanctions in case of non-compliance to climate change regulations? What are these sanctions? In case of no sanctions, are adaptation efforts voluntary?

Operational Level

Aggregation Statements
Are climate adaptation efforts communicated between infrastructure owners?

Appendix C: coding, clustering, and formalization of interview transcripts

This section gives an overview of how the interview transcripts were used in step 2 of the INA method. The coding was done in Atlas.ti to cluster the interview data. Based on these codes, networks were formed from which several important findings were derived and summarized in Appendix D. After the coding and clustering was done, institutional statements were written from the interview data by using the ABDICO syntax.

List of codes

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1 Interview City of Rotterdam

54 quotations

50 Codes:

○ Aanpassen normering / ○ Adaptatiestrategie / ○ Afhankelijkheid / ○ Afweging / ○ Afwegingskader / ○ Bedrijfsperspectief / ○ Bewustwording / ○ Brede aanpak / ○ Burgerperspectief / ○ Communicatie / ○ Contact / ○ Deltaprogramma Rijnmond-Drechtsteden / ○ Expertise / ○ Financiële afweging / ○ Geen gemeenschappelijk afwegingskader / ○ Geen gemeenschappelijke ambitie / ○ Gezamelijk / ○ Havenbedrijf - Afwegingskader / ○ Havenbedrijf Rotterdam / ○ Hitte / ○ Interactie / ○ Iteratie / ○ Kennisuitwisseling / ○ Keteneffecten / ○ Klimaatacceptatie / ○ Klimaateffecten / ○ Knelpunten / ○ Leerproces / ○ Lokaal / ○ Maatregelen / ○ Maatregelen - Afweging / ○ Maatschappelijke ontwrichting / ○ Maatwerk / ○ Meekoppelen / ○ Nationaal / ○ Onderbouwing / ○ Onderzoek / ○ Overstromingsrisico's / ○ Projecten / ○ Publieke versus private risicoafweging / ○ Relevantie / ○ Risicoafweging / ○ Risicodialoog - Aanpak / ○ Risicodialoog - Perceptie / ○ Risicoperceptie / ○ Risico's - Afweging / ○ Samenwerking / ○ Stresstest - Aanpak / ○ Stresstest - operationele aanpak / ○ Stresstesten - Haven

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2 Interview KNMI

48 quotations

27 Codes:

○ Aanpassen normering / ○ GL-scenario / ○ Kennisuitwisseling / ○ Klimaatacceptatie / ○ Klimaatdata / ○ Klimaateffecten / ○ KNMI / ○ KNMI - Aanpak / ○ KNMI - Positie havenbedrijf / ○ KNMI - Taak / ○ Maatwerk / ○ Neerslagstatistiek / ○ Onderbouwing / ○ Ondersteuning / ○ Relevantie / ○ Risicoperceptie / ○ Scenario's / ○ Stichting onderzoek waterschappen (STOWA) / ○ Stresstest - Aanpak / ○ Stresstest - operationele aanpak / ○

Stresstest - Perceptie / O Toepassing / O Transformatieprogramma / O Validatie / O Wet op het KNMI / O Wetten en kaders / O WH-scenario

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3 Interview Deltalinqs

27 quotations

29 Codes:

O Bewustwording / O BRZO (Bedrijvenrisico's zware ongevallen) / O Deltalinqs / O Deltalinqs - Beheerstaak / O Deltaprogramma - Waterveiligheid / O Deltaprogramma Rijnmond-Drechtsteden / O Deltares / O Droogte / O Financiële afweging / O Financiering / O Havenbedrijf Rotterdam / O Interactie / O Keteneffecten / O Klimaatacceptatie / O Kosten / O Maatregelen / O Maatregelen - Afweging / O Onduidelijkheid financiering / O Overstromingsrisico's / O Rijksoverheid / O Risicoafweging / O Risicodialogen / O Risicodialoog - Aanpak / O Risico's - Afweging / O Rotterdamse haven / O Royal Haskoning DHV / O Stresstesten - Haven / O Veiligheidsregio / O Verantwoordelijkheid

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4 Interview Port of Rotterdam

46 quotations

45 Codes:

O Afhankelijkheid / O Afwegingskader / O Ambiguïteit risicodrager / O Bedrijfsperspectief / O Commitment / O Contact / O Coördinerende rol / O Deltaprogramma Rijnmond-Drechtsteden / O Expertise / O Financiële afweging / O Financiering / O Gebiedsnoodplan / O Gebruikers / O Geen gemeenschappelijk afwegingskader / O Gemeente Rotterdam / O Haven - Risicodialoog / O Havenbedrijf - Aanpak / O Havenbedrijf - Afwegingskader / O Informatie-uitwisseling / O Isolatie / O Iteratie / O Keteneffecten / O Klimaatacceptatie / O Klimaateffecten / O Kosten / O Lange termijn-visie / O Leerproces / O Maatregelen / O Maatregelen - Afweging / O Maatwerk / O Meekoppelen / O Menselijk leed / O Milieu / O Normen / O Onduidelijkheid financiering / O Risicoafweging / O Risicoperceptie / O RWS / O Samenwerking / O Schade / O Stresstesten - Haven / O Terugkoppeling / O Verantwoordelijkheid / O Verschillende eigendommen / O Wetten en kaders

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5 Interview ProRail

113 quotations

71 Codes:

O Afhankelijkheid / O Afweging / O Ambiguïteit risicodrager / O Ambitie / O Beheerder / O Brede aanpak / O Communicatie / O Deltares / O Droogte / O Droogte - gevolgen / O Eenduidigheid / O Eenmalig / O Financiële afweging / O Geen gemeenschappelijk afwegingskader / O Geen gemeenschappelijke ambitie / O Gemeente

Rotterdam / ○ Gemeente Rotterdam - Beheerderstaak / ○ Green Deal GWW (Grond- weg en waterbouw) / ○ Groot impactgebied / ○ Horizon / ○ Hulpmiddel / ○ Investeringsfonds / ○ Isolatie / ○ Iteratie / ○ Kennisuitwisseling / ○ Klein impactgebied / ○ Klimaatacceptatie / ○ Knelpunten / ○ Kosten / ○ Lange besluitvorming / ○ Lokaal / ○ Maatregel / ○ Maatregelen / ○ Maatregelen - Afweging / ○ Nationaal / ○ Omgevingsvisies / ○ Omgevingswet / ○ Omgevingswet - Functie / ○ Ondersteuning / ○ Onderzoek / ○ Onduidelijkheid financiering / ○ Overstromingsrisico's / ○ Preventief / ○ ProRail / ○ ProRail - Beheerderstaak / ○ ProRail - Beheersgebied / ○ Provincie / ○ Risicodialogen / ○ Risicodialoog - Aanpak / ○ Risicodialoog - Perceptie / ○ Risicoprofiel / ○ Risico's - Afweging / ○ Rotterdamse haven / ○ Royal Haskoning DHV / ○ RWS / ○ Samenwerking / ○ Spoornetwerk / ○ Stresstest - Aanpak / ○ Stresstest - Beheersgebied / ○ Stresstest - operationele aanpak / ○ Stresstesten - Haven / ○ TenneT / ○ Tool / ○ Variëteit / ○ Veiligheidsregio / ○ Verschillende eigendommen / ○ Verschuiving / ○ Waterschappen / ○ Weersextremen / ○ Weinig aandacht samenhang risico's / ○ Wetten en kaders

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6 Interview Provincie 1

43 quotations

33 Codes:

○ Communicatie / ○ Covenant - Klimaatadaptief Bouwen / ○ Financiële afweging / ○ Functionele eisen / ○ Gebiedsontwikkeling / ○ Geen gemeenschappelijke ambitie / ○ Havenbedrijf Rotterdam / ○ Interactie / ○ Isolatie / ○ Iteratie / ○ Keteneffecten / ○ Klimaatacceptatie / ○ Klimaateffecten / ○ Lokaal / ○ Maatregelen / ○ Maatwerk / ○ Meekoppelen / ○ Nationaal / ○ Omgevingsvisies / ○ Onduidelijkheid financiering / ○ Projecten / ○ Provincie / ○ Risicoafweging / ○ Risicodialoog - Aanpak / ○ Risicodialoog - Perceptie / ○ Risicoperceptie / ○ Risico's - Afweging / ○ Rotterdamse haven / ○ Stresstest - Aanpak / ○ Stresstest - operationele aanpak / ○ Stresstest - Perceptie / ○ Validatie / ○ Verschillende eigendommen

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7 Interview Provincie 2

25 quotations

17 Codes:

○ CROW / ○ Financiële afweging / ○ Geen gemeenschappelijk afwegingskader / ○ Geen gemeenschappelijke ambitie / ○ Iteratie / ○ Leerproces / ○ Maatregelen - Afweging / ○ Ondersteuning / ○ Onzekere toekomst / ○ Risicoafweging / ○ Risicodialoog - Aanpak / ○ Risicodialoog - Perceptie / ○ Risicoperceptie / ○ Risico's - Afweging / ○ Stresstest - Aanpak / ○ Stresstest - Perceptie / ○ Veiligheidsregio

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8 Interview RWS road 1

48 quotations

42 Codes:

○ Aanpassen normering / ○ Contact / ○ Deltaprogramma - Waterveiligheid / ○ Deltares / ○ Expertise / ○ Financiële afweging / ○ Financiering / ○ Geen gemeenschappelijke ambitie / ○ Hoofdwegen / ○ Imagoschade / ○ Instrumenten / ○ Isolatie / ○ Iteratie / ○ Kennisdiensten / ○ Kennisuitwisseling / ○ Kernteam klimaatbestendige netwerken / ○ Klimaatacceptatie / ○ Klimaateffecten / ○ Knelpunten / ○ Leerproces / ○ Maatregelen / ○ Maatwerk / ○ Meekoppelen / ○ MIRT / ○ Nationale omgevingsvisie / ○ Omgevingsvisies / ○ Ondersteuning / ○ Onderzoek / ○ Regionale diensten / ○ Risicoafweging / ○ Risicodialogen / ○ Risicodialoog - Aanpak / ○ Risicodialoog - Perceptie / ○ Risico's - Afweging / ○ RWS - Beheerstaak / ○ RWS - Verantwoordelijkheid / ○ Samenwerking / ○ Service Level Agreements / ○ Stresstest - operationele aanpak / ○ Stresstest - Perceptie / ○ Vaarwegen / ○ Wetten en kaders

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9 Interview RWS road 2

27 quotations

32 Codes:

○ Afhankelijkheid / ○ Afstemming / ○ Ambigu / ○ Communicatie / ○ Contact / ○ Droogte / ○ Droogte - gevolgen / ○ Financiering / ○ Geen gemeenschappelijke ambitie / ○ Gezamelijk / ○ Hitte / ○ Isolatie / ○ Iteratie / ○ Klimaateffecten / ○ Maatwerk / ○ Meekoppelen / ○ Neerslag / ○ Ondersteuning / ○ Onderzoek / ○ Overstromingsrisico's / ○ Risicodialoog - Aanpak / ○ Risicodialoog - Perceptie / ○ Risicoperceptie / ○ RWS - Beheerstaak / ○ RWS - Verantwoordelijkheid / ○ Samenwerking / ○ Scenario's / ○ Stresstest - Aanpak / ○ Stresstest - Beheersgebied / ○ Stresstest - Perceptie / ○ Terugkoppeling / ○ Verschillende eigendommen

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10 Interview RWS road 3

38 quotations

34 Codes:

○ Aanpassen normering / ○ Afhankelijkheid / ○ Afweging / ○ Deltaprogramma - Waterveiligheid / ○ Deltaprogramma Rijnmond-Drechtsteden / ○ Ervaring / ○ Financiering / ○ Gebiedsoverstijgend / ○ Geen gemeenschappelijk afwegingskader / ○ Gezamelijk / ○ Havenbedrijf - Afwegingskader / ○ Hitte / ○ Imagoschade / ○ Klimaatacceptatie / ○ Knelpunten / ○ Kosten / ○ Lange besluitvorming / ○ Maatregelen / ○ Maatregelen - Afweging / ○ Maatschappelijke ontwrichting / ○ Meekoppelen / ○ Menselijk leed / ○ MIRT / ○ Normen / ○ Publieke versus private risicoafweging / ○ Regionale diensten / ○ Risicoafweging / ○ Risicodialoog - Perceptie / ○ RWS / ○ Stresstest - Aanpak / ○ Stresstesten - Horizon / ○ Verschillend besef urgentie asset managers / ○ Verschillende eigendommen / ○ Wetten en kaders

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11 Interview RWS water

42 quotations

38 Codes:

○ Afhankelijkheid / ○ Afstemming / ○ Afweging / ○ Belanghebbenden / ○ Communicatie / ○ Contact / ○ Deltaprogramma - Waterveiligheid / ○ Deltaprogramma - Zoetwater / ○ Dynamisch / ○ Eenduidigheid / ○ Expertise / ○ Financiële afweging / ○ Financiering / ○ Geen gemeenschappelijk afwegingskader / ○ Geen gemeenschappelijke ambitie / ○ Gezamelijk / ○ Hoofdwegen / ○ Informatie-uitwisseling / ○ Interactie / ○ Iteratie / ○ Kennisuitwisseling / ○ Kruisingen / ○ Kwaliteitstoets / ○ Leerproces / ○ Maatregelen / ○ Maatwerk / ○ Omgevingsanalyse / ○ Onderzoek / ○ Onduidelijkheid financiering / ○ Risicoafweging / ○ Risicodialoog - Aanpak / ○ Risicodialoog - Perceptie / ○ RWS - Verantwoordelijkheid / ○ Spoornetwerk / ○ Stresstest - Aanpak / ○ Stresstest - operationele aanpak / ○ Vaarwegen / ○ Wetten en kaders

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12 Interview LSNed

19 quotations

15 Codes:

○ Buisleidingen / ○ Contact / ○ Deltaprogramma - Waterveiligheid / ○ Havenbedrijf Rotterdam / ○ Hoogwater / ○ Kruisingen / ○ Leidingeigenaren / ○ LSNED / ○ LSNED - Beheerderstaak / ○ LSNED - Beheersgebied / ○ POV project / ○ Risicoperceptie / ○ Samenwerking / ○ Stresstest - Perceptie / ○ Waterschap Hollandse Delta

Examples of networks in Atlas.ti

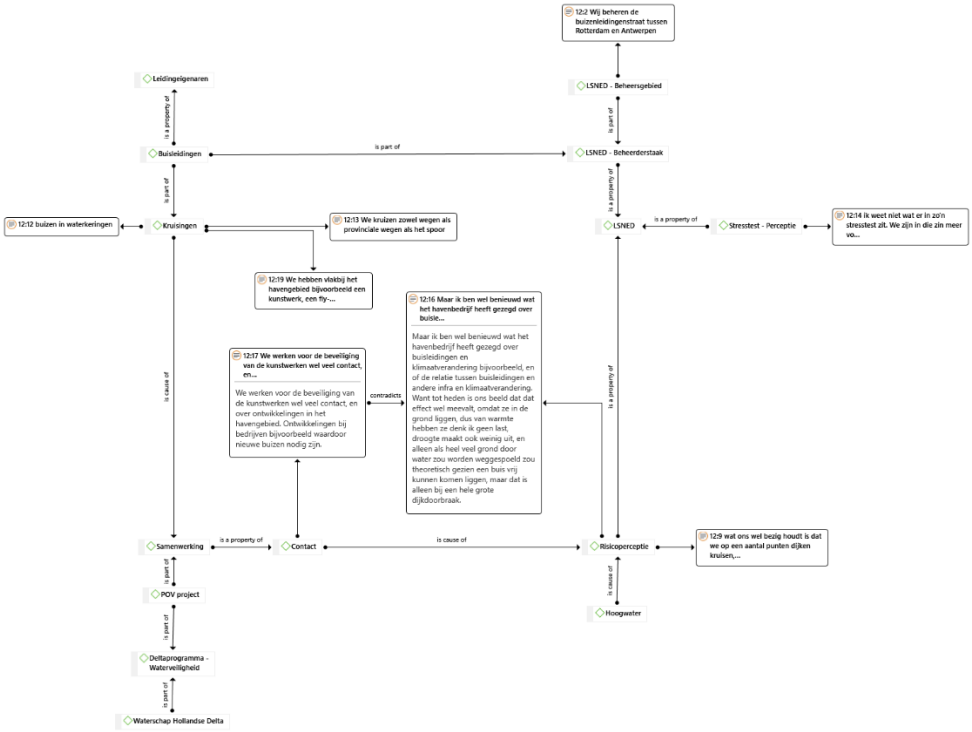


Figure C.1: an example of the networks made for the interview transcripts.

Figure C.1 and Figure C.2 depict examples of networks made in Atlas.ti. In the Network-function, all the codes (rectangles with green diamonds) can be linked to each other. It is also possible to select quotations belonging to a code, and only incorporate that particular quotation in the network (Figure rectangles with orange circles). Two individual codes can be linked to each other according to the following relations:

- Code A **contradicts** Code B
- Code A **is a** Code B
- Code A **is a property of** Code B
- Code A **is associated with** Code B
- Code A **is a cause of** Code B
- Code A **is part of** Code B

Individual quotations can be related to each other according to the following links:

- Quotation A **is continued by** Quotation B
- Quotation A **contradicts** Quotation B
- Quotation A **criticizes** Quotation B
- Quotation A **discusses** Quotation B
- Quotation A **describes** Quotation B
- Quotation A **explains** Quotation B
- Quotation A **justifies** Quotation B
- Quotation A **supports** Quotation B

From the network in Figure C.1, several findings can be derived:

- For pipelines, the biggest risks are perceived to be water hazards and floods. Drought and heat are not found to be impacts that can damage the pipelines significantly.
- The motivation to engage in climate adaptation for this actor came from a regional waterboard that contacted the actor. On its own, the actor did not previously engage in climate adaptation efforts or research. Climate adaptation efforts of actors operating in the same region may increase the perceived urgency of actors to engage in climate adaptation activities.
- Not all infrastructure owners whose infrastructures cross pipelines have reached out to pipeline owners to discuss possibilities for collaborative research or risk dialogues. The actor did not know what the impact of failure of those infrastructures would be on the pipelines it owns. Actors are therefore very dependent on each other to receive information on the impacts of climatic hazards.

Figure C.2 shows a part of another network which was constructed using an interview transcript. From this part, several conclusions can be drawn:

- Risk dialogues are a format in which actors share knowledge, point out important risks for infrastructures, and conduct a risk assessment.

- In risk dialogues one of the most crucial points of discussion is overcoming the ambiguity of who is financing the measures. When an actor brings a risk forward, it is not always the case that this actor is the responsible party in financing measures to prevent these risks. Often times, measures are necessary on grounds or infrastructures who are owned by other parties. However, it is not clear who is responsible for financing the measures: the party who perceives the risks, or the party who can reduce the risks through climate adaptation action?
- Conducting the risk dialogues is difficult for national infrastructure managers because each part of the infrastructure network brings new actors and therefore new risk perceptions to the risk dialogues.
- On the one hand, actors mention that climate adaptation is a learning process, and that actors need to become aware of and understand the risks that others perceive. On the other hand, they desire a more structured approach to doing this, through a common risk assessment framework for instance.
- This risk assessment framework is perceived to help in the weighing and prioritizing of short-, medium-, and long-term costs and benefits of climate adaptation policies.
- The risk assessment framework might also serve the connections and dependencies of different risks in an area. Currently, the differences in the risk perceptions may be so large, that a short-list of several big risks is created, and that only several actors continue to negotiate about each risk only. This has been a way to reduce the complexity but at the same time turns the attention away from the dependencies that exist between the risks.

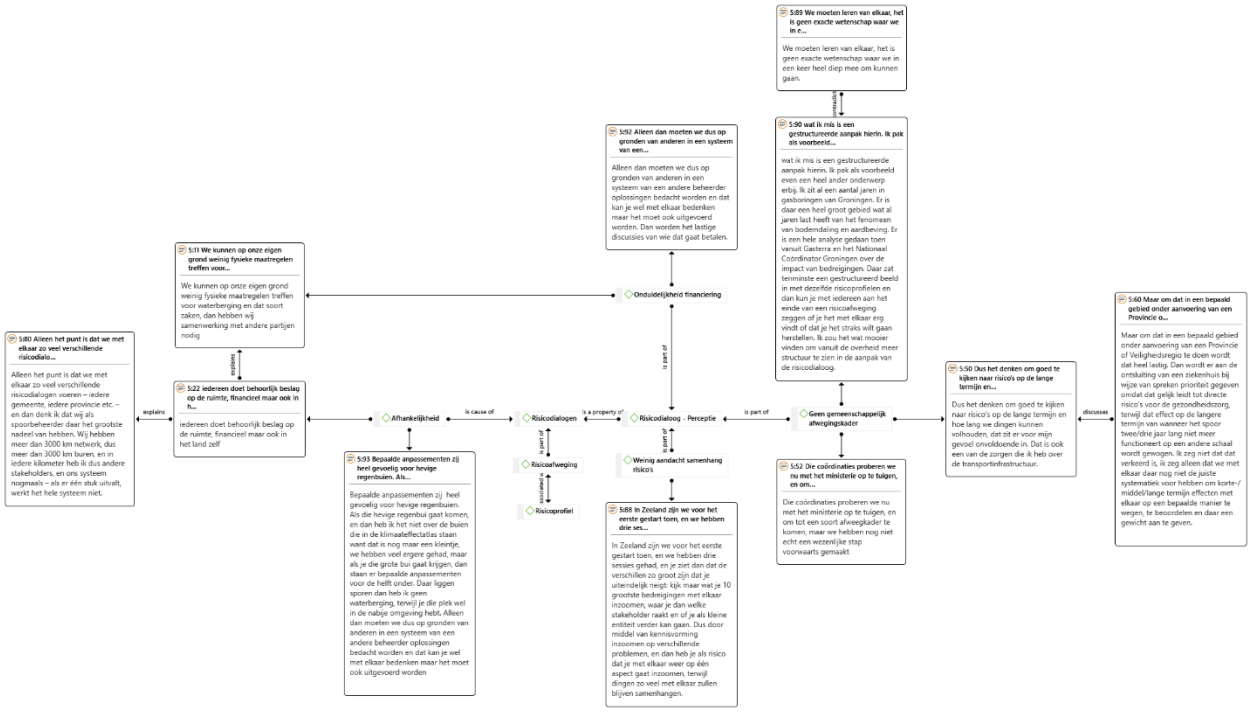


Figure C.2: an example of part of a networks made for the interview transcripts.

Applying ABDICO to an interview transcript

In subsection 3.3.2, nine steps were given to write institutional statements from interview transcripts. To demonstrate the application of the steps, the following section of an interview transcript is considered:

"The process is very simple, in the first place we turn to the analysis of Deltares and Royal Haskoning. They provide an initial overview of the flood risks in the ports' area, in this case the Maasvlakte area. We have done this for every area outside of Dordrecht – the Europort area was one of the last ones actually, and then we look at different points in time in the future under different chances of recurrence of different types of floods – so you get the risks first. Next you make a trade-off, what are the consequences of a potential flood, and these can be very different. A container terminal owner might look very differently at the consequences than a refinery. And if for example, water flows under the cranes, they might start shifting and the entire cargo is gone. It might take a while before such a risk occurs, but when it happens, it has major impacts. Those impacts are different for every company and each company has its own level of tolerance for water. So that means that you have to enter into discussions with each other."

1. Identify sentences as initial units of observations.

	Units of observation
1.	The process is very simple, in the first place we turn to the analysis of Deltares and Royal Haskoning.
2.	They provide an initial overview of the flood risks in the ports' area, in this case the Maasvlakte area.
3.	We have done this for every area outside of Dordrecht – the Europort area was one of the last ones actually, and then we look at different points in time in the future under different chances of recurrence of different types of floods – so you get the risks first.
4.	Next you make a trade-off, what are the consequences of a potential flood, and these can be very different.
5.	A container terminal owner might look very differently at the consequences than a refinery.
6.	And if for example, water flows under the cranes, they might start shifting and the entire cargo is gone.
7.	It might take a while before such a risk occurs, but when it happens, it has major impacts.
8.	Those impacts are different for every company and each company has its own level of tolerance for water.
9.	So that means that you have to enter into discussions with each other.

2. Mark de **verbs** in case they have an action (the "what" in a sentence) along with them in each sentence. Specify the pronouns.

	Units of observation
1.	The process is very simple, in the first place we **turn to** the analysis of Deltares and Royal Haskoning.
2.	They **provide** an initial overview of the flood risks in the ports' area, in this case the Maasvlakte area.
3.	We **have done** this (turn to the analysis) for every area outside of Dordrecht – the Europort area was one of the last ones actually, and then we **look at** different points in time in the future under different chances of recurrence of different types of floods – so you **get** the risks first.
4.	Next you **make** a trade-off, what are the consequences of a potential flood, and these can be very different.
5.	A container terminal owner **might look** very differently at the consequences than a refinery.
6.	And if for example, water flows under the cranes, they **might start shifting** and the entire cargo is gone.
7.	It might take a while before such a risk occurs, but when it happens, it has major impacts.
8.	Those impacts are different for every company and each company **has** its own level of tolerance for water.
9.	So that **means** that you **have to enter** into discussions with each other.

3. Mark the subject as well in each sentence and specify the pronouns. Write down the attributes [A] and aim [I].

	Units of observation	A	I
1.	The process is very simple, in the first place **we** (the Port of Rotterdam) **turn to** the analysis of Deltares and Royal Haskoning.	The Port of Rotterdam	turn to
2.	**They** (Deltares and Royal Haskoning) **provide** an initial overview of the flood risks in the ports' area, in this case the Maasvlakte area.	Deltares and Royal Haskoning	provide
3.	**We** (the Port of Rotterdam) **have done this** (turn to the analysis) for every area outside of Dordrecht – the Europort area was one of the last ones actually, and then **we** (the Port of Rotterdam) **look at** different points in time in the future under different chances of recurrence of different types of floods – so **you** (Deltares and Royal Haskoning) **get** the risks first.	The Port of Rotterdam	turn to
		The Port of Rotterdam	looks at
		Deltares and Royal Haskoning	get
4.	Next **you** (the Port of Rotterdam) **make** a trade-off, what are the consequences of a potential flood, and these can be very different.	The Port of Rotterdam	make
5.	**A container terminal owner might look** very differently at the consequences than a refinery.	-	-
6.	And if for example, water flows under the cranes, they (the cranes) might start shifting and the entire cargo is gone.	-	-
7.	It might take a while before such a risk occurs, but when it happens, it has major impacts.	-	-
8.	Those impacts are different for every company and **each company has** its own level of tolerance for water.	Each company	has
9.	So that means that **you** (ambiguous who is referred to) have to **enter** into discussions with each other.	Ambiguous	enter

4. Mark de **conditions** under which the actions are conducted in each sentence. If there is no condition in the sentence, it may still be derived implicitly from the information in the unit of observation.

	Units of observation	A	I	C
1.	The process is very simple, in the first place we (the Port of Rotterdam) turn to the analysis of Deltares and Royal Haskoning.	The Port of Rotterdam	turn to	if analysis has been constructed
2.	They (Deltares and Royal Haskoning) provide an initial overview of the flood risks in the ports' area, in this case the Maasvlakte area.	Deltares and Royal Haskoning	provide	if flood risk analysis is commissioned
3.	We (the Port of Rotterdam) have done this (turn to the analysis) for every area outside of Dordrecht – the Europort area was one of the last ones actually, and then we (the Port of Rotterdam) look at different points in time in the future under different chances of recurrence of different types of floods – so you (Deltares and Royal Haskoning) get the risks first.	The Port of Rotterdam	turn to	if the analysis has been constructed
		The Port of Rotterdam	looks at	if the analysis has been constructed
		Deltares and Royal Haskoning	get	-
4.	Next you (the Port of Rotterdam) make a trade-off, what are the consequences of a potential flood, and these can be very different.	The Port of Rotterdam	make	if flood risks are known
5.	A container terminal owner might look very differently at the consequences than a refinery.	A container terminal owner	-	-
6.	And if for example, water flows under the cranes, they (the cranes) might start shifting and the entire cargo is gone.	-	-	-
7.	It might take a while before such a risk occurs, but when it happens, it has major impacts.	-	-	-
8.	Those impacts are different for every company and each company has its own level of tolerance for water.	Each company	has	*always*
9.	So that means that you (ambiguous who is referred to) have to enter into discussions with each other.	Ambiguous	enter	-

5. Mark the object in the units of observation.

	Units of observation	A	B	I	C
1.	The process is very simple, in the first place we (the Port of Rotterdam) turn to **the analysis** of Deltares and Royal Haskoning.	The Port of Rotterdam	the analysis	turn to	if analysis has been constructed
2.	They (Deltares and Royal Haskoning) provide an initial overview of the flood risks in the ports' area, in this case the Maasvlakte area.	Deltares and Royal Haskoning	initial overview of flood risks	provide	if flood risk analysis is commissioned
3.	We (the Port of Rotterdam) have done this (turn to the analysis) for every area outside of Dordrecht – the Europort area was one of the last ones actually, and then we (the Port of Rotterdam) look at different points in time in the future under different chances of recurrence of different types of floods – so you (Deltares and Royal Haskoning) get the **risks** first.	The Port of Rotterdam	the analysis	turn to	if the analysis has been constructed
		The Port of Rotterdam	different points in time in the future	looks at	if the analysis has been constructed
		Deltares and Royal Haskoning	risks	get	-
4.	Next you (the Port of Rotterdam) make a **trade-off**, what are the **consequences of a potential flood**, and these can be very different.	The Port of Rotterdam	trade-off (consequences of a potential flood)	make	if flood risks are known
5.	A container terminal owner might look very differently at **the consequences** than a refinery.	A container terminal owner	the consequences	might look very differently at	-
6.	And if for example, water flows under the cranes, they (the cranes) might start shifting and the entire cargo is gone.	-	-	-	-
7.	It might take a while before such a risk occurs, but when it happens, it has major impacts.	-	-	-	-
8.	Those impacts are different for every company and each company has its own **level of tolerance for water**.	Each company	level of water tolerance	has its own	*always*
9.	So that means that you (ambiguous who is referred to) have to enter (into) **discussions** with each other.	Ambiguous	discussions	enter	-

6. Add, further specify, or rewrite components in each remaining unit of analysis by looking at information in the surrounding sentences (the other units of analysis).

	Units of observation	A	B	I	C
1.	The process is very simple, in the first place we (the Port of Rotterdam) turn to the analysis of Deltares and Royal Haskoning.	The Port of Rotterdam	the analysis	turn to	if analysis has been constructed
2.	They (Deltares and Royal Haskoning) provide an initial overview of the flood risks in the ports' area, in this case the Maasvlakte area.	Deltares and Royal Haskoning	initial overview of flood risks	provide	if flood risk analysis is commissioned
3.	We (the Port of Rotterdam) have done this (turn to the analysis) for every area outside of Dordrecht – the Europort area was one of the last ones actually, and then we (the Port of Rotterdam) look at different points in time in the future under different chances of recurrence of different types of floods – so you (Deltares and Royal Haskoning) get the risks first.	The Port of Rotterdam	the analysis	turn to	if the analysis has been constructed
		Deltares and Royal Haskoning	different points in time in the future	looks at	if the analysis has been constructed
4.	Next you (the Port of Rotterdam) make a trade-off, what are the consequences of a potential flood, and these can be very different.	The Port of Rotterdam	trade-off (consequences of a potential flood)	make	if flood risks are known
5.	A container terminal owner might look very differently at the consequences than a refinery.	-	-	-	-
6.	And if for example, water flows under the cranes, they (the cranes) might start shifting and the entire cargo is gone.	-	the consequences	might look very differently at	-
7.	It might take a while before such a risk occurs, but when it happens, it has major impacts.	-	-	-	-
8.	Those impacts are different for every company and each company has its own level of tolerance for water.	Each company	level of water tolerance	has its own	*always*
9.	So that means that you (ambiguous who is referred) have to enter into discussions with each other.	-	-	-	-

7. Determine the presence of a deontic for each unit of analysis.

	Units of observation	A	B	D	I	C
1.	The process is very simple, in the first place we (the Port of Rotterdam) turn to the analysis of Deltares and Royal Haskoning.	The Port of Rotterdam	the analysis		turn to	if analysis has been constructed
2.	They (Deltares and Royal Haskoning) provide an initial overview of the flood risks in the ports' area, in this case the Maasvlakte area.	Deltares and Royal Haskoning	initial overview of flood risks	must	provide	if flood risk analysis is commissioned
3.	We (the Port of Rotterdam) have done this (turn to the analysis) for every area outside of Dordrecht – the Europort area was one of the last ones actually, and then we (the Port of Rotterdam) look at different points in time in the future under different chances of recurrence of different types of floods – so you (Deltares and Royal Haskoning) get the risks first.	The Port of Rotterdam	the analysis		turn to	if the analysis has been constructed
		Deltares and Royal Haskoning	different points in time in the future		looks at	if the analysis has been constructed
4.	Next you (the Port of Rotterdam) make a trade-off, what are the consequences of a potential flood, and these can be very different.	The Port of Rotterdam	trade-off (consequences of a potential flood)		make	if flood risks are known
5.	A container terminal owner might look very differently at the consequences than a refinery.	-	-	-	-	-
6.	And if for example, water flows under the cranes, they (the cranes) might start shifting and the entire cargo is gone.	-	the consequences	-	might look very differently at	-
7.	It might take a while before such a risk occurs, but when it happens, it has major impacts.	-	-	-	-	-
8.	Those impacts are different for every company and each company has its own level of tolerance for water.	Each company	level of water tolerance	-	has its own	*always*
9.	So that means that you (ambiguous who is referred to) have to enter into discussions with each other.	-	-	-	-	-

8. Determine the presence of any tangible or emotional sanctions in each unit of analysis. In this example, no sanctions were identified.

	Units of observation	A	B	D	I	C
1.	The process is very simple, in the first place we (the Port of Rotterdam) turn to the analysis of Deltares and Royal Haskoning.	The Port of Rotterdam	the analysis		turn to	if analysis has been constructed
2.	They (Deltares and Royal Haskoning) provide an initial overview of the flood risks **in** the ports' area, in this case the Maasvlakte area.	Deltares and Royal Haskoning	initial overview of flood risks		provide	if flood risk analysis is commissioned
3.	We (the Port of Rotterdam) have done this (turn to the analysis) for every area outside of Dordrecht – the Europort area was one of the last ones actually, and then we (the Port of Rotterdam) look at different points in time in the future under different chances of recurrence of different types of floods – so you (Deltares and Royal Haskoning) get the risks first.	The Port of Rotterdam	the analysis		turn to	if the analysis has been constructed
		Deltares and Royal Haskoning	different points in time in the future		looks at	if the analysis has been constructed
4.	Next you (the Port of Rotterdam) make a trade-off, what are the consequences of a potential flood, and these can be very different.	The Port of Rotterdam	trade-off (consequences of a potential flood)		make	if flood risks are known
5.	A container terminal owner might look very differently at the consequences than a refinery.	-	-	-	-	-
6.	And if for example, water flows under the cranes, they (the cranes) might start shifting and the entire cargo is gone.	-	the consequences	-	might look very differently at	-
7.	It might take a while before such a risk occurs, but when it happens, it has major impacts.	-	-	-	-	-
8.	Those impacts are different for every company and each company has its own level of tolerance for water.	Each company	level of water tolerance	-	has its own	*always*
9.	So that means that you (ambiguous who is referred to) have to enter into discussions with each other.	-	-	-	-	-

9. Code all units of observation as rules, norms, or strategies. The statements below have been derived from the table. The first statement was formulated since it implicitly followed from the quote. While the second statement did not contain a formal explicit sanction in the statement, it was written as a rule since conducting the action is a formal responsibility.

	Institutional Statements	Type
1.	[A] The Port of Rotterdam [D] may [I] commission [B] a flood risk analysis [C] if risk aware.	Norm
2.	[A] Deltares and Royal Haskoning [D] must [I] provide [B] a flood risk analysis [C] if flood risk analysis is commissioned.	Rule
3.	[A] The Port of Rotterdam [I] looks at [B] different points in time in the future in the flood risk analysis [C] if the analysis has been conducted.	Strategy
4.	[A] The Port of Rotterdam [I] makes a [B] trade-off regarding consequences of a potential flood [C] if the flood risk analysis is available.	Strategy
5.	[A] Each company [I] considers [B] its own level of water tolerance [C] *always*.	Strategy

Appendix D: overview of narratives

In this section, an overview is given of the narratives that were found from the semi-structured interviews. These findings are detected through the discourse analysis and the networks which were constructed in Atlas.ti (Appendix C).

Diversity in climatic impacts and the policy-making processes

"It is important to point out that not all climatic impacts influence all infrastructures to the same extent or in the same manner."

In the Netherlands, there are four large themes which are defined in the national adaptation waterlogging, heat stress, drought, and sea-level rise. According to the Delta Programme for Spatial Adaptation, all the provinces, municipalities, waterboards, and infrastructure owners need to make stress tests, in which they include these four themes. In practice however, not all four themes are studied at the same level of detail by all stakeholders. There are several reasons for this.

First of all, themes related to water safety, in this case waterlogging and sea-level rise, are generally more developed when it comes to the rules and regulations to which infrastructures have to comply. For instance, national roads have norms for rainwater drainage to prevent wet road surfaces and accidents. Themes such as drought and heat, have only recently received more attention since the warm summer of 2018. However, even in the case of water safety where rules and regulations for construction exist, it is clear to infrastructure owners that the baseline conditions in these institutions have to be revised. In the case of the directive for rainwater drainage, that prescribes showers that roads must be capable of draining, it was found that the directive needed to be changed after research by Rijkswaterstaat (executive agency of the Ministry of Infrastructure and Water Management).

Second of all, it is important to point out that not all climatic impacts influence all infrastructures to the same extent or the same manner. In the case of railways, heat is very important because it can lead to rail buckling. The melting on roads occurs at higher levels of heat, and may vary depending on the material used in the roads. Not only the material usage however, but also the overall network performance of the infrastructures plays an important role here. According to Dutch railway owner ProRail, a single weak link immediately impacts the performance of the entire railway network, while in the case of road or waterway infrastructures, it is easier for vehicles to make detours or change routes. Furthermore, the impacts can be extremely multifaceted. The impacts of heat are particularly diverse. Examples are lower groundwater levels, drying-out of agricultural land, and reduced fresh water supply. For local governments such as the municipality of Rotterdam, problems due to heat are even more urgent because heat directly impacts the well-being and quality of life of citizens, in particular vulnerable groups in society. Moreover, even when the impacts on infrastructures are the same, the consequences may be worse for infrastructures more frequently used for the transportation of goods and peoples. The diversity of the climatic impacts imply that across different impacts, areas, infrastructures, and policy domains, a large group of actors have a stake in joining the so-called risk dialogues.

Climate risk acceptance: large discrepancies between actors

Contrary to the description of risk dialogues in the Delta Programme of Spatial Adaptation, stakeholders perceived that risk dialogues are iterative, occur at different levels, and have different topics. Prior to the risk dialogues, the topic needs to be specified by the initiator of the dialogue. This can be a local decision-maker like a municipality, but also a national government body like Rijkswaterstaat. The respondents were not always clear about who is expected to initiate the risk dialogues. However, in the case of infrastructures, there was a general tendency to expect from national government bodies, such as the Province or Rijkswaterstaat, to coordinate the risk dialogues. This is because the interdependencies between transport infrastructures and other networks such as those for energy and water supply can cause impacts on a very large scale in case of infrastructure failure. Through more national coordination, the idea is to prevent different local municipalities from repeatedly approaching parties such as transmission system operators and water companies with the same infrastructure risks.

However, this does not mean that risk dialogues do not occur on local levels at all. A risk dialogue is rather perceived as a certain style of engaging in dialogue rather than a specific moment when actors come together. This became evident from the manner in which actors described the risk dialogue: for the municipality of Rotterdam, going to a specific neighbourhood and discussing potential local initiatives for climate adaptation with citizens was seen as a risk dialogue. Government bodies at higher levels, such as the province of South-Holland and Rijkswaterstaat, perceived risk dialogues as meetings with other actors who have a stake in joining the dialogue. From all the interviews, it became clear that the translation of findings about the climatic impacts to actual policy-making is tedious, more so on a national level than on a local level. There are several important reasons for this.

Isolated and diverse research efforts

> "When the parties conduct the stress tests for assessing the impacts of climate change, they do not incorporate the interdependencies between infrastructures, but focus on the infrastructures they own."

Infrastructure owners mentioned that they continuously communicated with each other. These communications occur since they are responsible for managing the respective infrastructures, and need to be aware of problems that infrastructure users might experience, especially for climatic impacts which were less prevalent in the past such as heat and drought. Rijkswaterstaat mentioned that during the drought in 2018, there was regular contact with waterway users about the bottlenecks they experienced: transhipment of containers, supplying raw materials, and carrying intermediary and end products were all difficulties waterway users were facing. The communications are therefore in particularly conducted for operational purposes. However, there have also been different research initiatives with different infrastructure owners collaborating with one another. Railway operator ProRail mentioned that together with Rijkswaterstaat and counterparts in Belgium and Luxembourg, a research was carried out to gain insights in the impact of climate change on the transportation of goods with different transport modalities. This was particularly important for goods arriving at ports in Rotterdam and Antwerp. However, when the parties conduct the stress tests for understanding the impacts of climate change, they do not incorporate the interdependencies between infrastructures, but rather focus on the infrastructures they own. Parties have different working styles in assessing the impacts on infrastructures as well. The province of South-Holland started with a 'quick-scan' for the provincial roads and waterways. Based on the results of this quick-scan, a deeper stress test would be made at vulnerable locations, which focus on the underlying causes of the vulnerabilities and possible measures one can take as a result. ProRail had a similar approach for the railways.

Rijkswaterstaat however, chose several spots in the Netherlands for an immediate in-depth analysis, while for other areas, a quick-scan was made. The public parties are all conducting stress tests in parallel at the moment, while at the same time they learn from others how they are conducting stress tests. Despite these information exchanges, the stress tests also do not contain any assessment of effects from one infrastructure on the other.

Another noticeable finding was the discrepancy in working style of the Port of Rotterdam and the businesses which are situated on the outskirts of the dikes. The Port of Rotterdam takes part in the working group of Rijnmond-Drechtsteden, a subprogramme of the water safety plan in the Delta Programme. Contrary to the stress tests in the Delta Programme, the port of Rotterdam has solely focussed on sea-level rises in the tests. Moreover, while there has been communication with transport infrastructure owners such as ProRail, Rijkswaterstaat, and the Province of South-Holland in the Rijnmond-Drechtsteden working group, the Province mentioned that the harbour has not contacted them in the context of spatial adaptation in the Delta programme.

No common framework for risk assessment

"The absence of a common systematic approach for prioritizing and weighing different short-, mid-, and long-term impacts hampers the translation of the found risks to an actual implementation agenda."

Several stakeholders mentioned that the variety in research efforts on an operational level can make it difficult to compare the results of the different stress tests. The province of South-Holland for instance, indicated that in the municipal network, all the municipalities have access to the same information and the same base conditions when making the stress tests. However, several respondents mentioned that is possible for different parties to consider different levels of rainfall, even when the same climatic scenarios are being used.

What makes the whole decision-procedure more complex however, is not so much the differences in making the stress tests, but the way in which parties *perceive* and *assess* the risks. For climate adaptation, the Ministry of Infrastructure and Water Management decided not to determine any standards for climate-resistance. The purpose of this absence of exact norms is that stakeholders come to an agreement together on what climatic impacts they find acceptable for different infrastructures at different sites. This means however that every stakeholder may develop its own standards for risk severity and decide by itself what is severe and what is acceptable. So while the impacts of climate change are known, not all stakeholders have the same risk perception.

During risk dialogues, stakeholders with different risk dialogues need to come to a common ground of what the risks are in the environment and which ones need to be prioritized. However, respondents mentioned how this weighing of short-term and long-term risks is problematic during these dialogues. An example that a respondent gave was that during one risk dialogue, the priority was given to preserving the accessibility of hospitals over improving the functioning of the rail network over a longer period of time. This was because assuring the accessibility of hospitals would generate immediate positive impacts for the health care sector. The absence of a common systematic approach for prioritizing and weighing different short-, mid-, and long-term impacts hampers the translation of the found risks to an actual implementation agenda. This problem is more common on a national scale than during risk dialogues on a local scale. On a local scale, stakeholders working on projects have longer histories of working together and over time have developed a deeper understanding of the risks involved. Moreover, the solutions they discuss during their risk dialogues are to be implemented on a relatively smaller scale than solutions for national infrastructures.

The larger the network, the more stakeholders are involved, the more negotiations need to be conducted, the more risk perceptions of other will be needed to account for, and the longer it takes to form a common ground about the impacts and necessary measures.

Ambiguity regarding the financial responsibilities of the parties involved

"Every infrastructure is situated in an area with multiple ownerships, and sometimes, the cause of the climatic hazards lead to the conclusion that interventions in the areas of other stakeholders are necessary."

While research efforts focus on finding the vulnerabilities on separate infrastructures, this does not mean that measures which can reduce these problems can only be carried out on these same infrastructures. Every infrastructure is situated in an area with multiple ownerships, and sometimes, the cause of the climatic hazards lead to the conclusion that interventions in the areas of other stakeholders are necessary. A very clear example was given by ProRail, the rail network owner. There are several points in the stress test where water logging is likely to cause problems for the rail network. However, in order to drain the water, water storage areas near the rails have to be used. These water storage areas are not owned by ProRail however, and might not have sufficient capacity for the amount of water from extreme weather circumstances. However, owners of these areas might perceive this differently, and be convinced that the areas can store enough rainwater. Even if there is agreement about the risks, the most important question becomes who is going to finance these measures. Is it the party who is capable of resolving problems on the other infrastructure, or is it the risk bearer, in this case, ProRail? There are no agreements on this and these disagreements are found to be the most challenging ones to discuss. This was particularly the case for infrastructure owners whose network spanned a very large area.

Public versus private objectives

"While financial performance is found to be the dominating criterion in the risk assessment, based on the respondents' answers, the reputation of decision-makers also impacts the risk acceptance."

Apart from financial performance, there were three other criteria which were mentioned to be important in parties' risk assessment: the image (or reputation) of a party, societal disruption, and the number of wounded or deceased citizens as a result of climatic hazards. While financial performance is found to be the dominating criterion in the risk assessment, based on the respondents' answers, the reputation of decision-makers also impacts the risk acceptance. One instance is when parties conduct dialogues with ordinary citizens. Citizens with a lower acceptability level than decision-makers may be very quick to decide that no single climatic hazard in their environment is acceptable to them. This may lead to decision-makers revising existing norms for water safety for instance or continue to negotiate on risk acceptance levels in order to keep political support.

Another point in this respect was the tension between public and private perspectives during negotiations. When discussing the climatic risks, public parties mentioned societal consequences, while private parties mainly focussed on economic damage and consequences. An example is when private companies prioritize economic criteria in the risk assessment of a potential flood. When a potential flood appears to have little economic consequences, the risk may be acceptable to the private firm, while a government agency sees that the impacts may propagate and cause large societal disruptions.

While the exact purpose of the risk dialogues is to come to a common understanding of these risks, it is found to be difficult to come to an agreement at times when a common framework for the risk assessment or objective had not been formulated.

Asset managers versus decision-makers

"These climatic hazards or disasters sometimes have very small probabilities as compared to events such as traffic accidents, which may give off the impression that they do not require immediate action"

Decision-makers and asset managers often have different perceptions of the urgency of climate adaptation options. Urgency here refers to the need to implement climate adaptation options: one may implement measures immediately, or choose to defer action to a later point in time. This urgency is among which assessed by looking at the probability that a climatic hazard or disaster may occur. These climatic hazards or disasters sometimes have very small probabilities as compared to events such as traffic accidents, which may give off the impression that they do not require immediate action. Asset managers may therefore be more likely to accept climatic hazards as compared to the decision-makers.

Trade-off in measures is between local projects and structural, large-scale solutions

"Climate adaptation measures with a long lead time, investments with a long life time, and potentially a large delay before the measures are actually implemented are more likely to be pushed further away in the future."

With regards to the implementation of climate adaptation options, it was found that on a local level, there is more progress in the risk dialogues and drawing an implementation agenda as compared to the national levels. Explanations which were given for this were a smaller group of actors who are involved, a shorter time-horizon, and a smaller area in which projects might be implemented in. Often times on a local level, the measures include smaller-scale projects in neighbourhoods, with a fixed budget, and many no-regret characteristics (the measures are good to implement irrespective of climate change). Climate adaptation measures with a long lead time, investments with a long life time, and potentially a large delay before the measures are actually implemented are more likely to be pushed further away in the future. While what is the risk of implementing many "quick-wins" is that they might not be effective for the network as a whole.

More national coordination, prioritization and specification of ambitions for climate adaptation is found to be desirable

"Having a common goal, or common criteria in mind to assess the risks significantly supports the decision-making process and the negotiations about risks and options to implement."

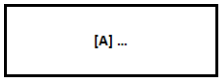
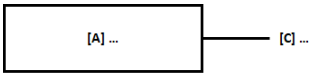
What was particularly an interesting finding was the tension between two lines of thought which came forward throughout the interviews. On one hand, almost all the respondents emphasised that climate adaptation is characterized by customisation. Which criteria play a role in the risk assessment and which measures are deemed to be effective are site-specific. This is why there are no fixed standards to which infrastructure owners have to comply. The idea is that what is acceptable must follow from the risk dialogues. On the other hand however, several respondents mentioned that having a common goal, or common criteria in mind to assess the risks significantly supports the decision-making process and the negotiations about risks and options to implement.

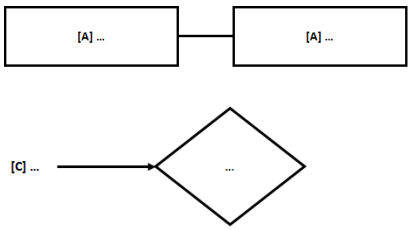
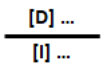
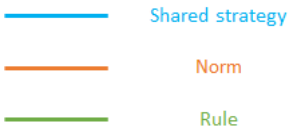
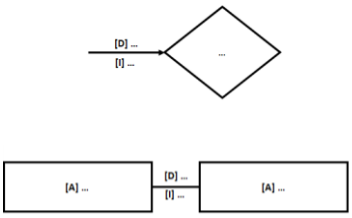
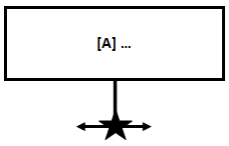
Appendix E: constructing and analysing Institutional Network Diagrams (INDs) surrounding the Port of Rotterdam

In this section, the construction and the analysis of the Institutional Network Diagrams (INDs) for the case study in this research is shown. The section first shows the original steps to drawing INDs as proposed in the prototype by Ghorbani et al. (2020). Please refer to section 3.4 for the improved series of steps and guidelines on how to analyse them. Next, the original INDs are shown, followed by their improved versions. Lastly, the original INDs are analysed by looking at institutional conflicts, network metrics, and links between the INDs.

Steps to drawing INDs

Table E.1: the original steps to drawing INDs as proposed in the prototype by Ghorbani et al. (2020).

Steps for drawing the Institutional Network Diagram (IND)				
Step		**Concept in IAD framework**	**Concept in ADICO syntax**	**Visual representation in IND**
1.	Define the action arena that forms the basis of the IND	Action arena	-	Title of the IND
2.	Determine what cluster of institutional statements define the action arena	Rules-in-use, attributes of community/ physical world	-	-
3.	Define the primary attribute(s): the attributes [A] of the institutional statement that activate outcomes or other decision-makers within the action arena.	Actor	**A**ttribute	
4.	Draw a link from the attribute to the condition, and write the condition(s) down following the institutional statement. The [C], if not set on default, interrupts a link or arrow.	Patterns of interactions	**A**ttribute **C**ondition	
5.	If the ADICO statement links to another ADICO statement, draw a link from the condition (or directly from the actor if condition is default) to another actor.	Outcomes	**A**ttribute **C**ondition **O**r else	

	Or: if the ADICO statement does not link to another statement, draw an arrow to an outcome (physical or non-physical) in a diamond (see step 8), or a sanction in a diamond with a dotted line.			
6.	Write the deontic and the aim next to the link/arrow that was drawn in step 5. Write [D] … and [I] ... to differentiate between deontic and aim.	Rules-in-use Outcomes	**D**eontic A**i**m	
7.	Use a colour code to distinguish between rules, norms and shared strategies. In this research, rules are green, norms are orange and shared strategies are blue lines. Not only the links/arrows are coloured, the corresponding written [D] and/or [I] are coloured as well.	Rules-in-use	ADICO ADIC AIC	
8.	If deontic and aim are written next to an arrow, draw a diamond for an physical or non-physical outcome or a diamond with a dotted line for a sanction. Or: If deontic and aim are written next to a link, draw the attribute for the ADICO statement that follows the statement (see step 5).	Outcomes Feedback		
9.	Repeat these steps until all ABDICO statements from step 2 have been incorporated. Check whether all ABDICO statements either lead to other ABDICO statements, or to an outcome/sanction.	-	-	-
10.	If two or more institutional statements yield different outcomes in the same action situation, a conflict has been identified. This is depicted with a black star. Here, institutional hierarchy should be addressed (see INA research step 5).	-	-	

Knowledge gathering for climate adaptation

The phase of knowledge gathering is drawn in two INDs: the first showing how research is conducted, and the second showing how vulnerability assessments are made based on these research efforts. Please also refer to section 4.2.2 for the explanation on the first part, on how research is conducted. Table E.2 shows the institutions which were identified for this first IND. The original corresponding IND is shown in Figure E.1, the improved IND is shown in Figure E.3.

Table E.2: the identified institutional statements showing how vulnerabilities are mapped through research in the knowledge gathering phase.

No.	Name	A	D Rule	I	C	O
R1	Constructing Climate Change Scenarios	The Royal Dutch Meteoro-logical Institute	must	publish climate change scenarios (W+, W-, G+, G-)	*default*	
			Norm			
N1	Probability analysis request (Port of Rotterdam)	The Port of Rotterdam	may	request a probability analysis of climatic hazards to **Royal Haskoning DHV**	for any sub-area of the port	
N2	Probability analysis request (Municipality of Rotterdam)	The Port of Rotterdam	may	request a probability analysis of climatic hazards to **Royal Haskoning DHV**	for any sub-area of the port	
N3	The Port of Rotterdam		may	request a flood risk analysis to an **external risk assessment group (HKV Lijn in Water, VU Amsterdam)**	if flood probability analysis is available	
N4	Stress test request (to ProRail)	The Ministry of Infrastructure and Water Management	may	order stress test construction to **ProRail**	if climate change scenarios are published	
N5	Stress test request (to RWS)	The Ministry of Infrastructure and Water Management	may	order stress test construction to **RWS**	if climate change scenarios are published	
N6	Stress test request (to the Province off South-Holland)	The Ministry of Infrastructure and Water Management	may	order stress test construction to the **Province of South-Holland**	if climate change scenarios are published	
N7	Stress test construction (ProRail)	ProRail	may	request a stress test to **Arcadis**	for the national rail network	
N8	Stress test construction (RWS)	RWS	May	request a stress test to **Deltares**	for the national road network	

N9	Stress test construction (Province of South-Holland)	The Province of South-Holland may	request a stress test to an **external stress test provider (Deltares, Nelen & Schuurman, and TNO)**	for the regional road and waterway network
Strategy				
S1	Stress test ProRail	Arcadis	constructs the stress test for ProRail	for water hazards, floods, heat, lightning and storm damage, wildlife fire, and subsidence; in the W+ and G-scenario; if requested by the **Ministry of Infrastructure and Water Management**
S2	Stress test RWS	Deltares	constructs the stress test for RWS	for heavy rainfall, ground water changes, drought, heat, and floods; in all four climate scenarios; if requested by the **Ministry of Infrastructure and Water Management**
S3	Climate Impact Atlas Province of South-Holland	The external stress test provider (Deltares, Nelen & Schuurman, and TNO)	constructs the climate impact atlas for the Province of South-Holland	for water hazards, drought, heat, floods, and subsidence; if requested by the **Ministry of Infrastructure and Water Management**
S4	Flood probability analysis	Royal Haskoning HDV	reports the flood probability analysis	if climate change scenarios are published; in the W+ and G-scenario; if requested by the **Port of Rotterdam**

S5	Flood risk analysis	The external risk assessment group (HKV Lijn in Water, VU Amsterdam)	constructs the flood risk analysis	If ordered by the **Port of Rotterdam**

After the climatic hazards are mapped, the maps show where the climate hazards are very severe and where the infrastructures may be vulnerable. Vulnerable here means that the highest category on a scale showing the severity of an impact applies. For example, if there is a scale showing extreme rainfall, the highest amount of rainfall is likely to occur in an area. Whether this vulnerability poses a risk that needs to be tackled collectively is something that actors need to determine together during the risk dialogues. Table E.3 shows the institutions for labelling areas as vulnerable or not. The information is based on the stress test of RWS (Deltares, 2020), the climate impact atlas of the Province of South-Holland (2018), and the guide for climate adaptation (ProRail, 2019). The original corresponding IND is shown in Figure E.2, and the improved IND is shown in Figure E.4. The IND shows that not all the impacts being assessed in the stress tests are considered when looking at the vulnerabilities. An example is the case of heat in the stress test in RWS. While it is an impact that is acknowledged in the stress test (Figure 16), it is not explicitly considered when labelling infrastructures as vulnerable. The reason was that it was not clear what exactly the impacts are on the infrastructures. For climatic hazards that are common between the infrastructure owners, like floods and heavy precipitation, the levels at which an infrastructure is potentially vulnerable differ between the different research outputs.

Table E.3: the identified institutional statements for the vulnerability assessments of the Province of South-Holland, ProRail, and RWS.

No.	Name	A D Strategy	I	C O
S6	Vulnerability assessment for subsidence (Province)	The Province of South-Holland	considers waterways to be vulnerable to subsidence	if climate impact atlas is available; if subsidence is beyond 2,5 mm per year
S7	Vulnerability assessment for drought (Province)	The Province of South-Holland	considers waterways to be vulnerable to drought	if climate impact atlas is available; if ground water levels chance more than 1,5 m
S8	Vulnerability assessment for heat and drought (Province)	The Province of South-Holland	considers roads to be vulnerable to heat and drought	if climate impact atlas is available; if the average temperature rise if 2 degrees Celsius in 2050; if infrastructure has high emissivity
S9	Vulnerability assessment for water hazards (Province)	The Province of South-Holland	considers roads to be vulnerable to water hazards	if climate impact atlas is available; if a peak rain shower of 100 mm in 2 hours occurs; if more than 30 cm

				of water is on the road
S10	Vulnerability assessment for floods (Province)	The Province of South-Holland	considers roads to be vulnerable to floods	if climate impact atlas is available; in case of a flood with a repetition time of 1:100 to 1:1000 per year (medium probability); if the maximum water depth is more than 50 cm
S11	Vulnerability assessment for water hazards (ProRail)	ProRail	considers railways to be vulnerable to water hazards	if the stress test for ProRail is available;
S12	Vulnerability assessment for drought (ProRail)	ProRail	considers railways to be vulnerable to drought	if the stress test for ProRail is available
S13	Vulnerability assessment for lightning and storm damage (ProRail)	ProRail	considers railways to be vulnerable to storm damage	if the stress test for ProRail is available
S14	Vulnerability assessment for floods (ProRail)	ProRail	considers railways to be vulnerable to floods	if the stress test for ProRail is available
S15	Vulnerability assessment for subsidence (ProRail)	ProRail	considers railways to be vulnerable to subsidence	if the stress test for ProRail is available
S16	Vulnerability assessment for heat (ProRail)	ProRail	considers railways to be vulnerable to heat	if the stress test for ProRail is available
S17	Vulnerability assessment for floods (RWS)	RWS	considers roads to be vulnerable to floods	if the stress test for RWS is available
S18	Vulnerability assessment for ground water changes (RWS)	RWS	considers roads to be vulnerable to ground water changes	if the stress test for RWS is available
S19	Vulnerability assessment for heavy rainfall (RWS)	RWS	considers roads to be vulnerable to heavy rainfall	if the stress test for RWS is available
S20	Vulnerability assessment for drought (RWS)	RWS	considers roads to be vulnerable to drought	if the stress test for RWS is available

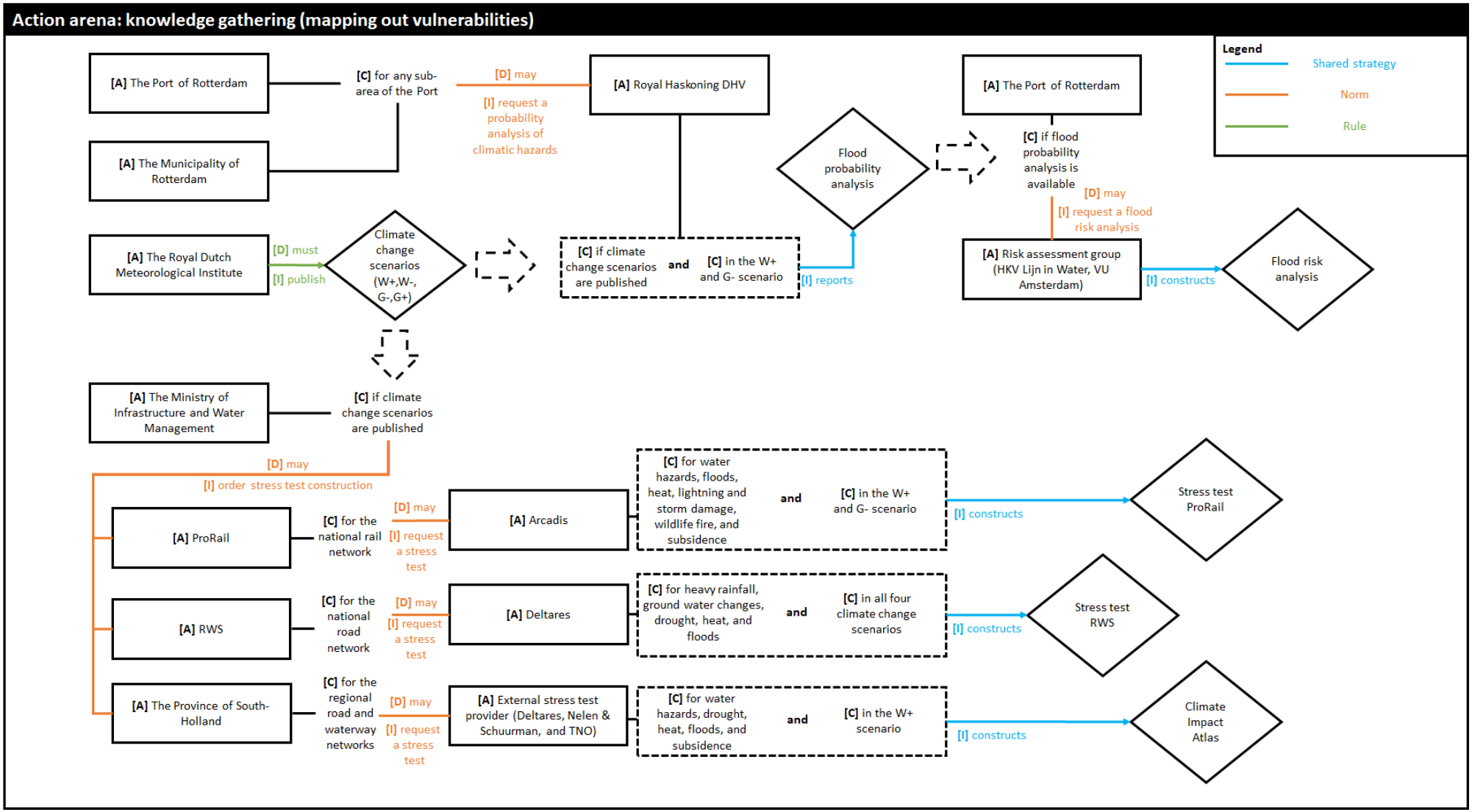


Figure E.1: the original IND for the knowledge gathering (mapping vulnerabilities)

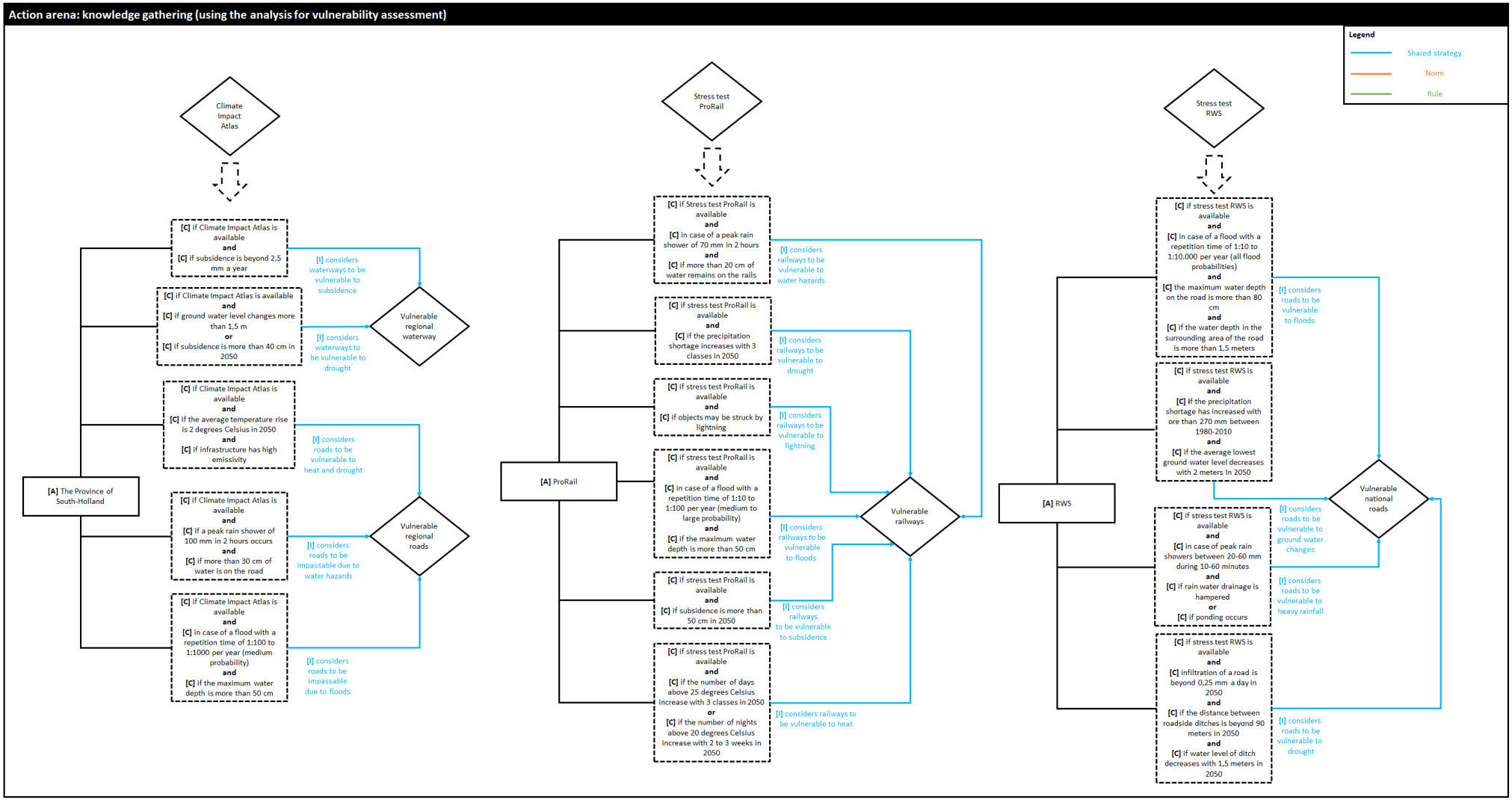


Figure E.2: the original IND for the knowledge gathering (using the analysis for vulnerability assessment)

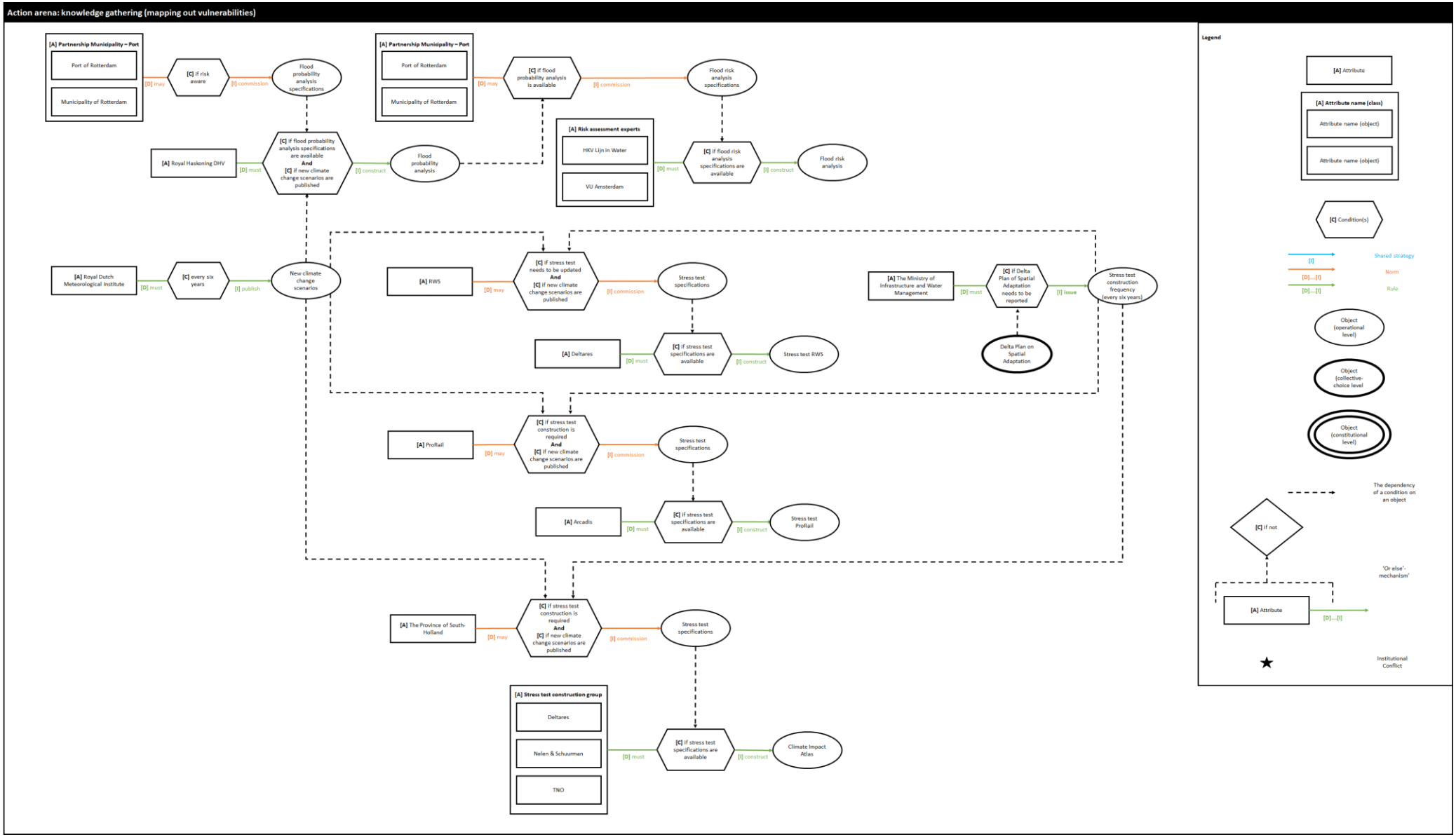


Figure E.3: the improved IND for the knowledge gathering (mapping vulnerabilities)

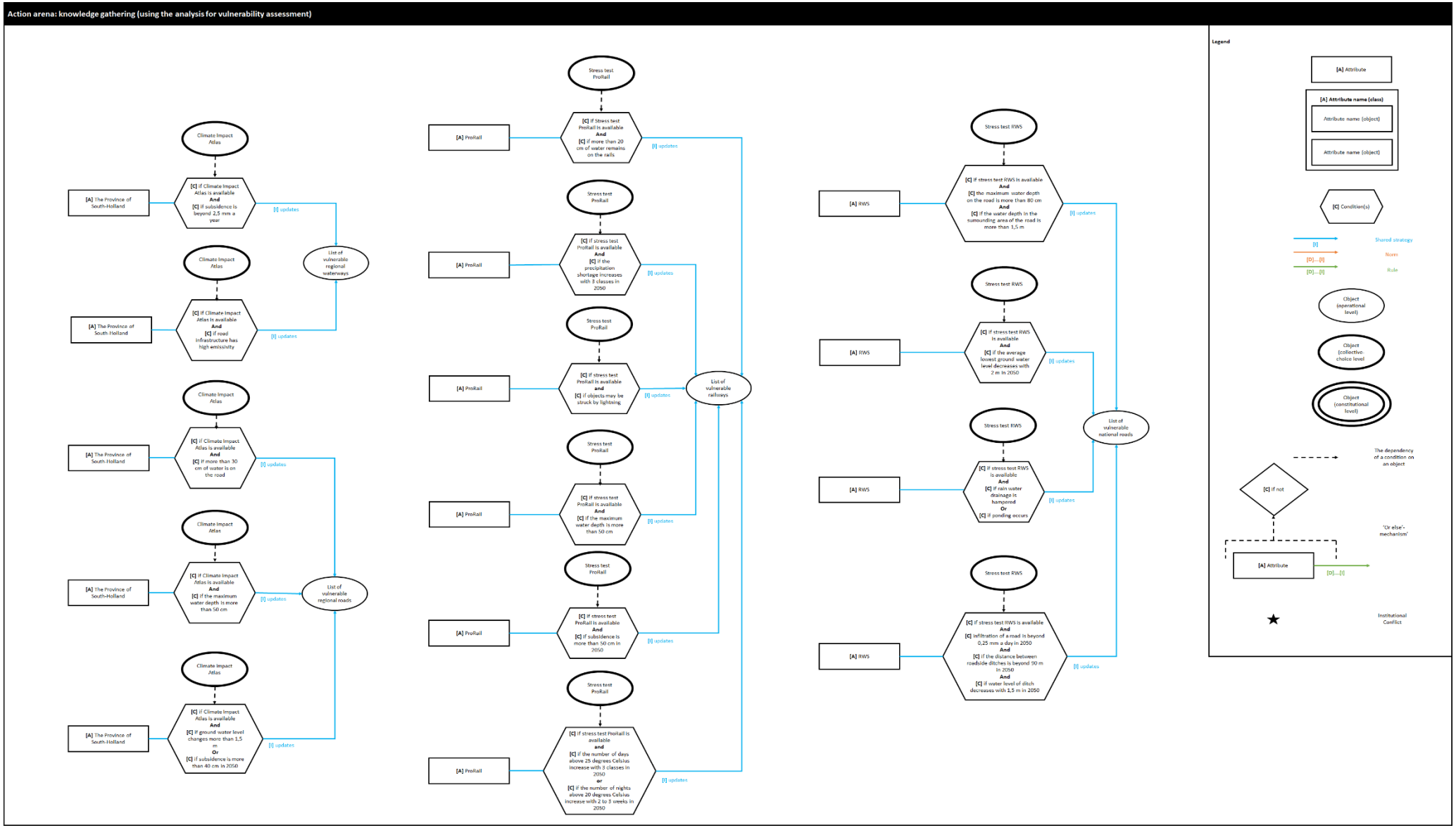


Figure E.4: the improved IND for the knowledge gathering (using the analysis for vulnerability assessment)

Conducting risk dialogues for climate adaptation

After the knowledge gathering phase, actors engage in risk dialogues. In this case study, the risk dialogue phase is split in two action arenas: one for the first workshop (risk dialogue I), and one for the second workshop (risk dialogue II). Please refer to section 4.2.3 for the full explanation of risk dialogue I. The institutional statements identified for this IND are shown in Table E.4. The original corresponding IND is shown in Figure E.5. The improved IND is shown in Figure E.7.

Table E.4: the identified institutional statements for risk dialogue I.

No.	Name	A	D	I	C	O
			Norm			
N10**	Usage of decision-framework by RWS	RWS	may	base acceptable chance of infrastructure failure on shared decision-framework	if shared decision framework is available	
N11**	Usage of decision-framework by ProRail	ProRail	may	base acceptable chance of infrastructure failure on shared decision-framework	if shared decision framework is available	
N12**	Usage of decision-framework by BRZO-companies	BRZO-companies	may	base acceptable chance of infrastructure failure on shared decision-framework	if shared decision framework is available	
			Strategy			
S21	Flood risk communication I (Port of Rotterdam)	The Port of Rotterdam		communicates flood probabilities to **RWS**	if flood probability analysis is available	
S22	Flood risk communication Ii (Port of Rotterdam)	The Port of Rotterdam		communicates flood probabilities to **ProRail**	if flood probability analysis is available	
S23	Flood risk communication I (Municipality of Rotterdam)	The Municipality of Rotterdam		communicates flood probabilities to **RWS**	if flood probability analysis is available	
S24	Flood risk communication II (Municipality of Rotterdam)	The Municipality of Rotterdam		communicates flood probabilities to **ProRail**	if flood probability analysis is available	
S25	Consequences of road infrastructure failure	RWS		reports consequences of failure based on electricity facilities of infrastructure	if national roads are connected to the Port; if vulnerabilities of RWS match the	

			to the **Port of Rotterdam**	findings of the flood probability analysis
S26	Consequences of rail infrastructure failure	ProRail	reports consequences of failure based on elevation, foundation, and electricity facilities of infrastructure to the **Port of Rotterdam**	if railways are connected to the Port; if vulnerabilities of ProRail match the findings of the flood probability analysis
S27	Communication of acceptable societal risks (individual and group risk)	The Province of South-Holland	reports acceptable individual and group risk to the **Port of Rotterdam**	*default*
S28	Shared decision-framework construction	The Port of Rotterdam	constructs a shared decision-framework	if flood risk analysis is available; for economic damage, environmental damage, and number of casualties
S29**	Usage of decision-framework by RWS	RWS	does not base acceptable chance of infrastructure failure on shared decision-framework	if shared decision framework is available
S30**	Usage of decision-framework by ProRail	ProRail	does not base acceptable chance of infrastructure failure on shared decision-framework	if shared decision framework is available
S31**	Usage of decision-framework by BRZO-companies	BRZO-companies	does not base acceptable chance of infrastructure failure on shared decision-framework	if shared decision framework is available
** institutional conflict				

During risk dialogue II, potential measures are selected based on their ability to reduce the risks as shown in the shared decision-framework and/or the risk matrices of the individual actors. It is therefore a cost-benefit analysis. Table E.5 shows the identified institutional statements for workshop II of the risk dialogue. The original and improved IND are shown in**Fout! Verwijzingsbron niet gevonden.** Figure E.6 and Figure E.8 respectively.

Table E.5: the identified institutional statements for risk dialogue II.

No.	Name	A	D Strategy	I	C	O
S32	Communicating acceptability of infrastructure failure (BRZO-companies)	BRZO-companies		expresses unacceptability of infrastructure failure to the **Port of Rotterdam**	if the chosen acceptable chance of infrastructure failure is exceeded; if the acceptable risk in the company's risk matrix is exceeded	
S33	Communicating acceptability of infrastructure failure (ProRail)	ProRail		expresses unacceptability of infrastructure failure to the **Port of Rotterdam**	if the chosen acceptable chance of infrastructure failure is exceeded; if the acceptable risk in its risk matrix is exceeded	
S34	Communicating acceptability of infrastructure failure (RWS)	RWS		expresses unacceptability of infrastructure failure to the **Port of Rotterdam**	if the chosen acceptable chance of infrastructure failure is exceeded; if the acceptable risk in its risk matrix is exceeded	
S35	Cost-benefit analysis request	The Port of Rotterdam		requests a cost-benefit analysis for potential measures to **Royal Haskoning DHV.**	if **BZRO-companies, ProRail, and RWS** have communicated their risk acceptance.	
S36	Potential measure selection	Royal Haskoning DHV		adds measure to potential measures	if damage reduction is greater than the cost of damage before the measure	
S37	Measure exclusion	Royal Haskoning DHV		excludes the measure	if damage reduction is less than the cost of	

				damage before the measure
S38	Final measure selection (BRZO-companies)	BRZO-companies	choose measure	for the potential measures; if measure is deemed to be easily adaptable over time; if measure is easy to implement technically and institutionally
S39	Final measure selection (ProRail)	ProRail	chooses measure	for the potential measures; if measure is deemed to be easily adaptable over time; if measure is easy to implement technically and institutionally
S40	Final measure selection (RWS)	RWS	chooses measure	for the potential measures; if measure is deemed to be easily adaptable over time; if measure is easy to implement technically and institutionally
S41	Final measure selection (Port of Rotterdam)	The Port of Rotterdam	chooses measure	for the potential measures; if measure is deemed to be easily adaptable over time; if measure is easy to implement technically and institutionally

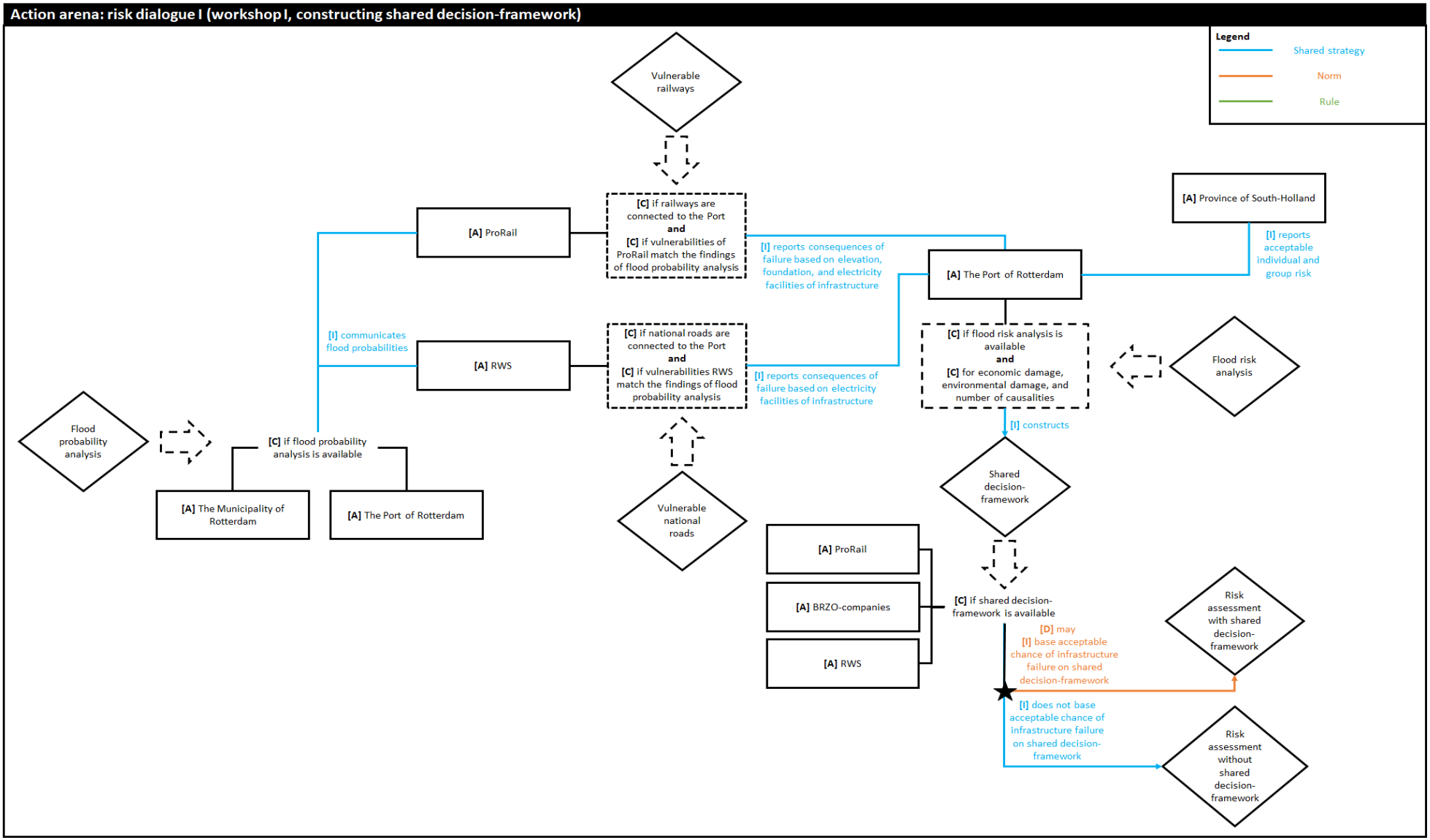


Figure E.5: the original IND for risk dialogue I.

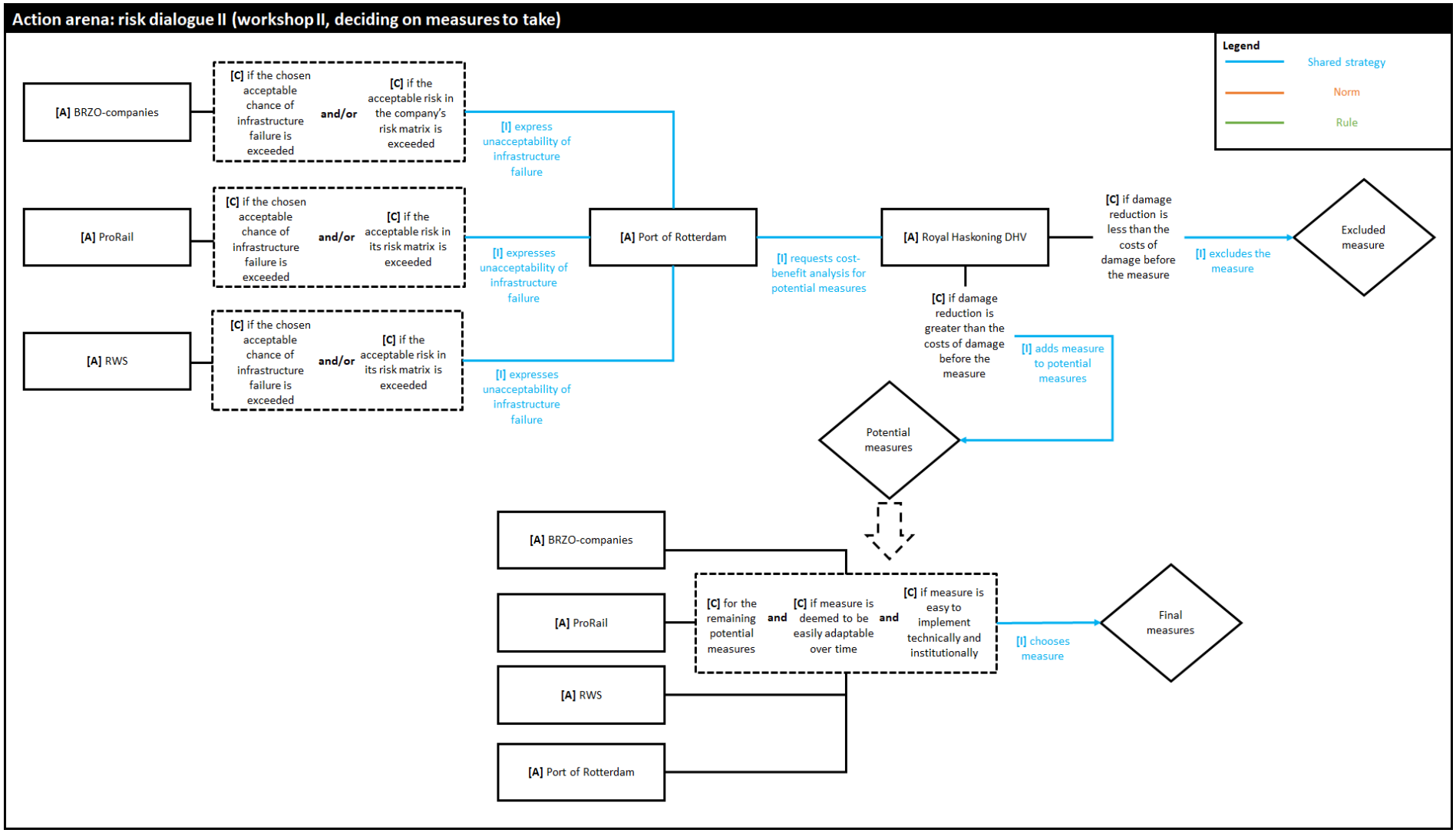


Figure E.6: the original IND for risk dialogue II.

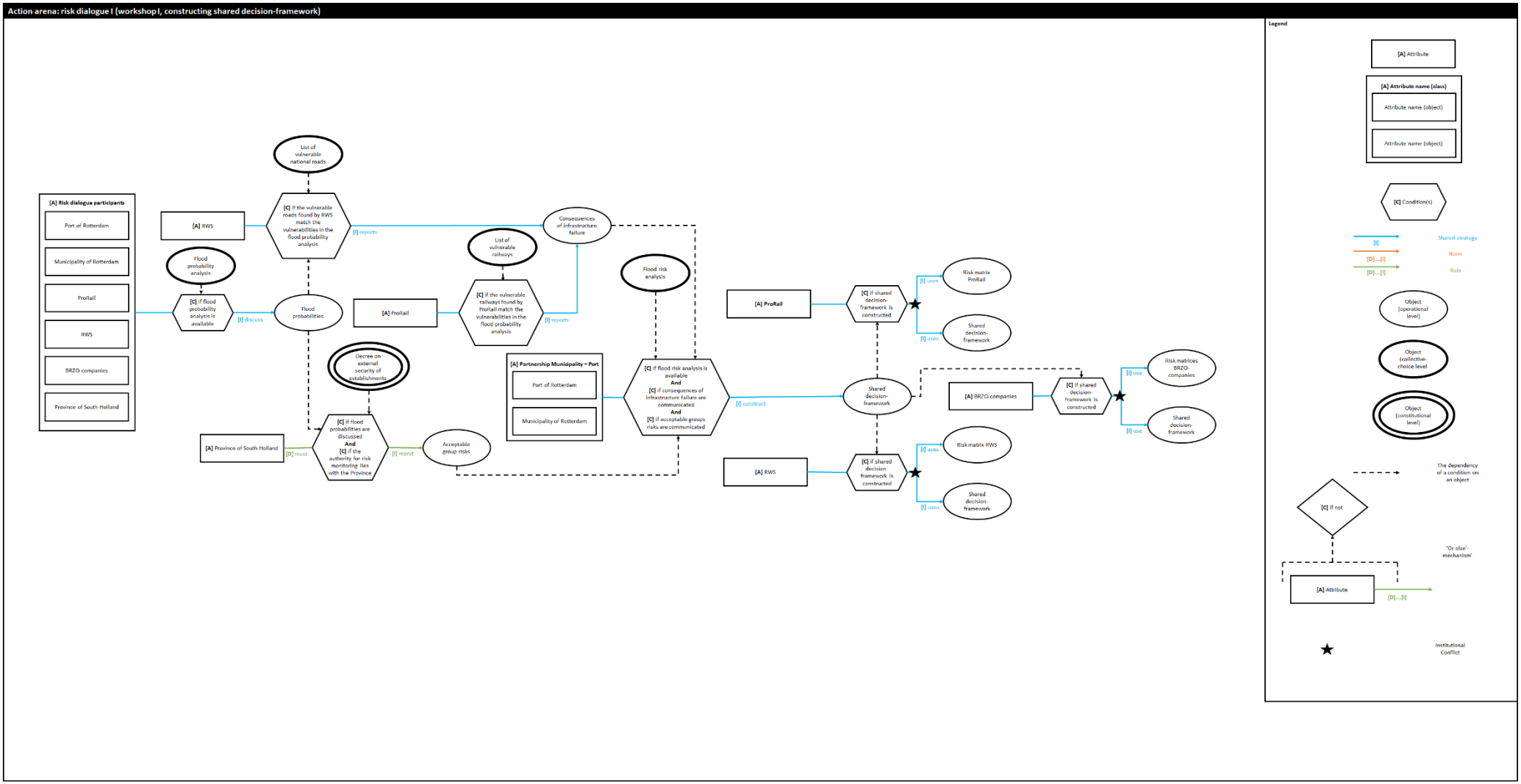


Figure E.7: the improved IND for risk dialogue I.

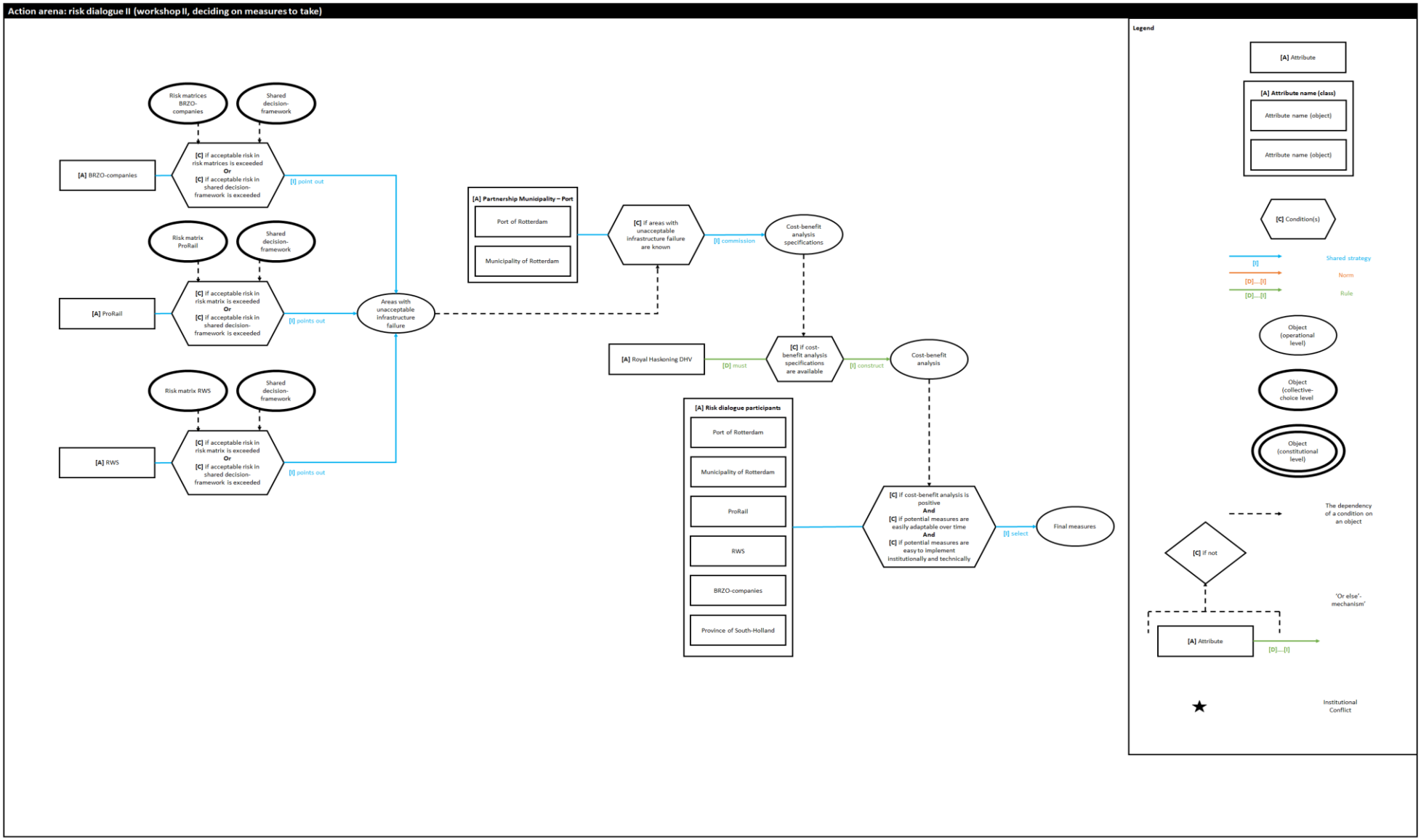


Figure E.8: the improved IND for risk dialogue II.

Drawing up implementation agenda

Drawing up an implementation agenda here means that measures are being planned out. From the interviews, it follows that in reality, none of the actors are in a phase were measures are actually being implemented at the moment. Therefore, two types of measures are incorporated in this IND which followed from the interviews, and which have the potential to be implemented in the context of climate adaptation surrounding the Port. The first measure relates to adapting the current emergency management plan of companies operating at the Port. The second type of adaptation measure relates to adaptation measures which protect infrastructures against water hazards. The institutions are shown in Table E.6, and the original corresponding IND is shown in Figure E.9. The improved version of the IND is shown in Figure E.10. From the original IND, an institutional conflict can be found which is related to the financing of the climate adaptation measures.

Table E.6: the identified institutions for drawing up an implementation agenda.

No.	Name	A	D	I	C	O
			Rule			
R2	Water safety risk communication	BRZO-companies	must	report on the company's water safety risks to the **Province of South-Holland**		R3/ R4
R3	Withholding permit	The Province of South-Holland	must	demand fine from **BRZO-company**	if individual risk is exceeded; if societal risk is exceeded	
R4	Fining the BRZO-company	The Province of South-Holland	must	withhold operating permit for **BRZO-company**	if individual risk is exceeded; if societal risk is exceeded	
R5	Company emergency shutdown	TenneT	must	shut down electricity provision to companies	if ordered by the **Port of Rotterdam**	
R5	Emergency management municipality	The Municipality of Rotterdam	must	instruct emergency services	if requested by the **Port of Rotterdam**	
R6**	Budget request for infrastructure plans	RWS	must	request budget from the **Ministry of Infrastructure and Water Management**	if **BRZO-companies or ProRail** report need for water storage areas	
			Norm			
N13	Electricity shut down order	The Port of Rotterdam	may	order electricity shut down at companies to **TenneT**	if water hazard emergency notification is given; if hazards exceed borders of the Port	
N14	Emergency help request	The Port of Rotterdam	may	send request for additional emergency aid to the **Municipality of Rotterdam**	if water hazard emergency notification is given; if hazards exceed borders of the Port	

N15	Flood defence consultation	The Province of South-Holland	may	consult **regional waterboards** for the actual strength of flood defences	if road is impassable; if the number of lost vehicle movements is beyond 600 movements per hour
N16	Delta Fund budget	Regional waterboards	may	request budget from Delta Fund	if flood defences need to be strengthened
Strategy					
S42	Shut down communication	BRZO-companies		communicates shut down order to the **Port of Rotterdam**	
S43	Water hazards communication (to RWS)	BRZO-companies		communicate the need for more rainwater drainage on roads to **RWS**	
S44	Water hazards communication (to Province of South-Holland)	BRZO-companies		communicate the need for more rainwater drainage on roads to the **Province of South-Holland**	
S45	Water storage area request	ProRail		communicates the need for more water storage areas to **RWS**	if remaining measures concern waterproofing railways; if railway crosses water storage areas
S46**	Financing by RWS	RWS		is not responsible for financing road adaptation measures	*default*
S47	Budget provision by Ministry	The Ministry of Infrastructure and Water Management		provides the budget	if requested by **RWS**

** institutional conflict

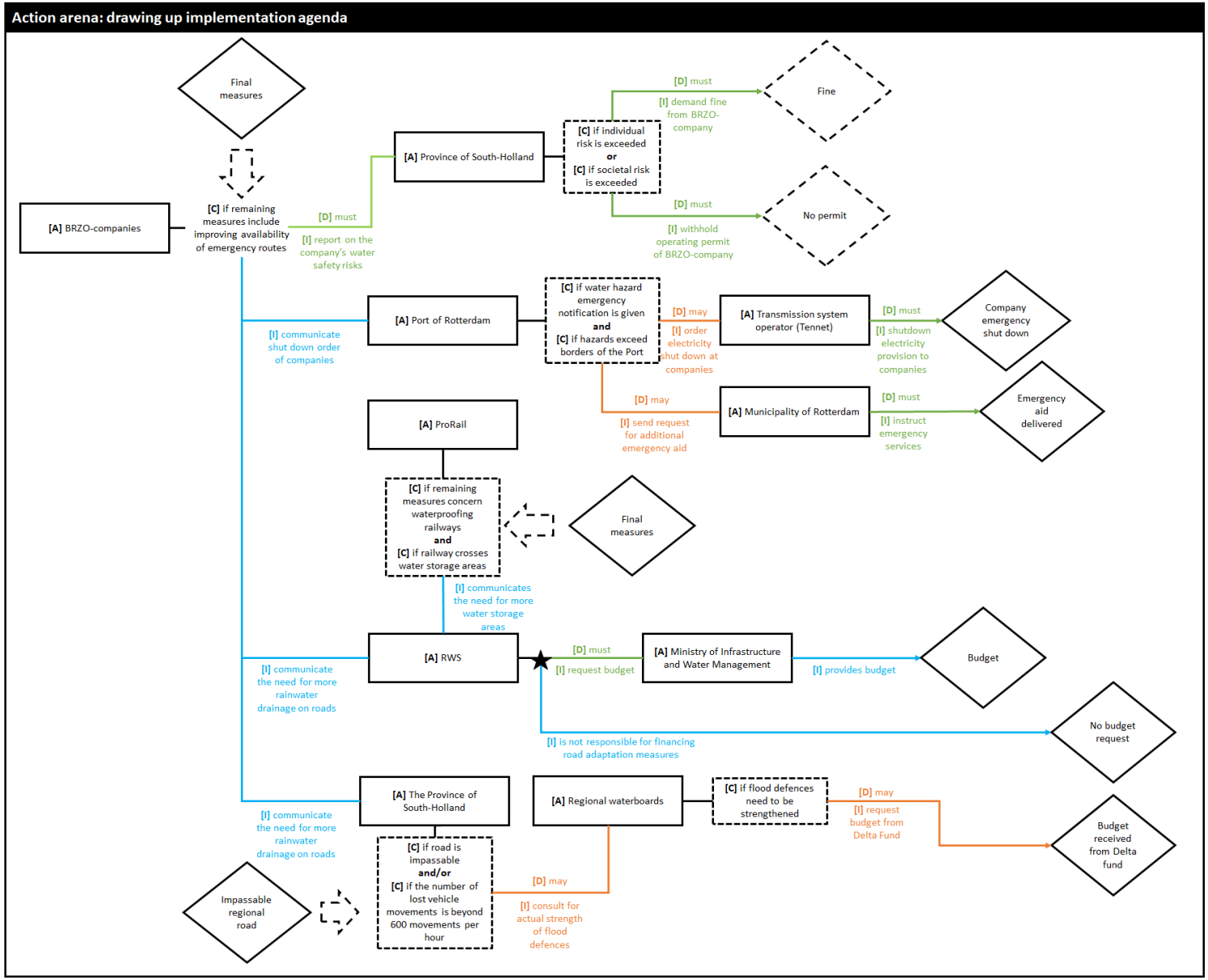


Figure E.9: the original IND for drawing up an implementation agenda.

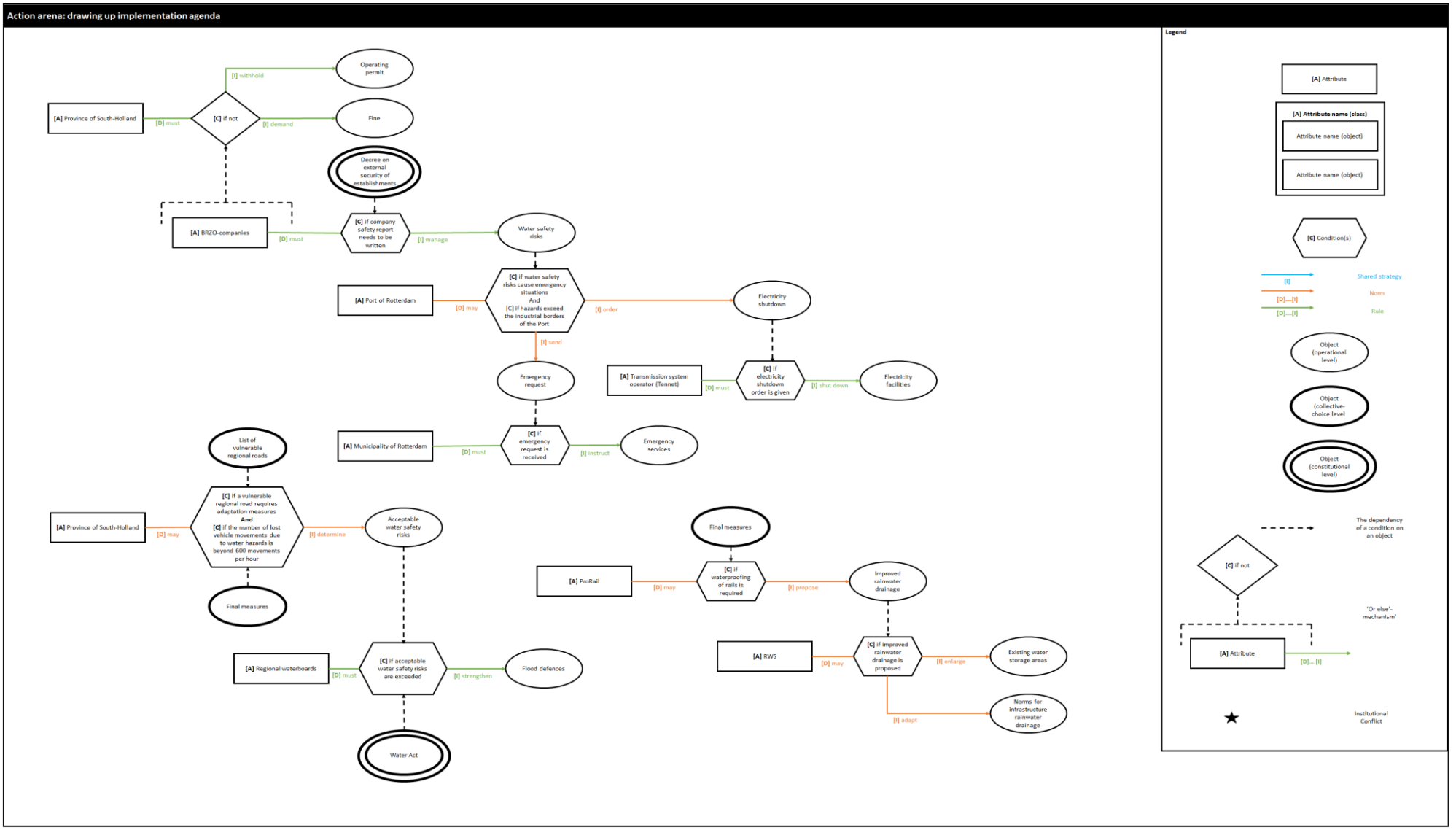


Figure E.10: the improved IND for drawing up an implementation agenda.

Appendix F: calculations IND network metrics

Table F.1 and Table F.2 show the calculations for the network metrics density, centrality and embeddedness that are discussed in chapter 4 and 5. Due to time constraints of this research, these network metrics have only been made for the original INDs, and not for the improved versions of the INDs.

Density is given through both the number of attributes as well as all the nodes (attributes and outcomes) and calculated by dividing the number of actual links by the number of possible links.

Table F.1: Density per IND

IND	# attributes	# nodes	#links between attributes	#links total	Possible #links between attributes	Possible #links	**Density (based on attributes only)**	**Density (based on all nodes)**
Knowledge gathering	12	22	9	19	66	231	0,136	0,082
Risk dialogue I	6	13	7	14	15	78	0,467	0,179
Risk dialogue II	5	8	4	10	10	28	0,400	0,357
Drawing up implementation agenda	9	19	6	16	36	171	0,167	0,094
Subtotal risk dialogue	11	21	11	24	25	106	0,867	0,537
Total	15	37	26	59	127	508	0,205	0,116
Average density							**0,292**	**0,178**

In blue: >1.00 centrality rank (4th column) and an >0.5 rank on embeddedness (5th column).

Table F.2: Level of centrality and embeddedness per attribute.

Attribute	#links per attribute	#links to other attributes	Level of centrality	Embedded-ness
RWS (Rijkswaterstaat)	16	6	2,474	0,375
ProRail	16	5	2,474	0,313
Port of Rotterdam	15	14	2,320	0,933
Province of South-Holland	13	6	2,010	0,462
BRZO-companies	8	5	1,237	0,625
Royal Haskoning DHV	6	3	0,928	0,500
Ministry of Infrastructure and Water Management	5	4	0,773	0,800
Municipality of Rotterdam	5	4	0,773	0,800
Transmission system operator (TenneT)	2	1	0,309	0,500
Regional waterboards	2	1	0,309	0,500
External stresstest provider (Deltares, Nelen & Schuurman, TNO)	2	1	0,309	0,500
Deltares	2	1	0,309	0,500
Arcadis	2	1	0,309	0,500
Risk assessment group (HKV Lijn in Water, VU Amsterdam)	2	1	0,309	0,500
Royal Dutch Meteorological Institute (KNMI)	1	0	0,155	0,000
Average	6,47		1,00	**0,52**