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Research article

# The shaping of anticipation: The networked development of inferential capacity in governing Southeast Asian deltas

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ABSTRACT

Motivated by foreseeable changes in the Earth's systems, governments across the world learn to anticipate the consequences. Understanding how such anticipation comes about should ease its further development. We therefore explore the central capacity within anticipatory governance: the capacity to infer future consequences. Such *inferential capacity* consists of tools, techniques, and practices increasing an agent's options to infer consequences. We examine the development of this capacity for two Southeast Asian deltas, using data from a multi-sited ethnography and a social network analysis. These methods combine the small-scale 'lived' perspective of agents and the multiscale network in which these agents deploy strategies to entrench tools, techniques, and practices for inferential capacity. Strategic choices in positioning for network effects and fostering reciprocity matter, while values and historical contingencies cannot be brushed aside.



## 1. Introduction

A coffee cup falls from a ledge and breaks; a cat anticipates the impact – and walks away. The cat readied its body, having perceived and inferred what it needed to do. Humans are more like cats than coffee cups in this regard. But are our societies? Throughout history and across the globe we have been mostly reactive to Earth's systems. Indeed, we have made headway in anticipating events going way beyond our intuitions and direct experiences, but we have still a long way to go. Our scientific tools, techniques, and practices have brought into collective awareness intricate ways in which Earth systems work at multiple scales to impact our future societies. More recently, governments have applied tools, techniques, and practices to become less reactive and more prepared for the high-dimensional, multiscale dynamics of Earth's phenomena.

Central to such anticipation is a government's capacity to infer consequences – its *inferential capacity*. How does such capacity form? What does it consist of and what does it do for us to modify our anticipation of unfolding, uncertain, and sometimes unprestatable events? Such questions are important. Inference within governance is vital in recognizing future risks, in settling plausible scenarios, in decomposing different perspectives in a complex future, or in engaging with the political and societal implications of a choice of policy. By orienting attention to techniques, tools, and practices, we argue the concept of inferential capacity enables an empirical account of how anticipatory governance forms. Understanding how a capacity to infer arises is not trivial. Anticipatory governance is needed to become prepared for shifts in climatic regimes and its multiscale consequences on many places on Earth.

To explore this concept of inferential capacity, to ground it and make it robust, we looked at the real-world development of the capacity to infer in governance. Two rivers in Southeast Asia, the Ayeryawaddy in Myanmar and the Chao Phraya in Thailand, have experienced and will face major changes from economic development, climate change, and demographic growth (Tessler et al., 2015). The Chao Phraya delta is dominated by the presence of the unplanned, flood-prone, and "sinking" megacity of Bangkok. The Ayeryawaddy delta, in contrast, is the second poorest region in Myanmar, large and agrarian. Adjacent lies the fast-growing, and much richer former capital Yangon. River systems are complex entities, both part of Earth systems and socio-technical systems, and sites for future demographic growth. They are exposed to small-scale events – such as flooding, water pollution, droughts, sedimentation, salinization, erosion, or land subsidence – and to larger events, such as sea-level rise induced by climate change or the impacts of an urbanizing and growing population. Governing

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such disparate events at different scales, and doing so to anticipate futures, requires expertise for inference.

In the period studied (2008–2018), Thailand and Myanmar showed a marked development of inferential capacity for the behavior of respectively the Chao Phraya river and the Ayeryawaddy river. Myanmar was a hermit state prior to 2008. In 2018 it was a site of rapid development. Neighboring Thailand (Bangkok in particular) became a regional hub for such expertise. The countries are neighbors with comparable pre-colonial histories and different (post-)colonial histories, resulting in different present capacities and needs and illuminating the importance of understanding local context in facilitating the development of inferential capacity.

Before we embark to study how it comes about in the real world, inferential capacity needs conceptual context and defining.

## 2. Conceptual framework: inferential capacity, anticipatory governance, and networks

'Inferential capacity' is a useful concept for getting a grip on some puzzling questions. How multi-scale environmental change works, for example, is such a puzzle (Galaz et al., 2012; Burch et al., 2018), and so is understanding what strategies agents use and best use for complex systems governance (Young 2017). Traditional environmental governance research usually does not treat these questions (Biermann 2009). It has been noted that such strategies must work in networks that tie together diverse institutions (Biermann 2014; Van der Ven et al., 2013; Young 2018).

Exploring what inferential capacity is requires a definition of its components ('inference' and 'capacity') and a distinction from what it is *not*. We take inference to be a 'jump' from one piece of information to the next (in particular: a premise to a consequence) in light of achieving a judgment. Capacity is defined here as the ability to put resources to work to meet a goal. Inferential capacity utilizes resources so a group can infer towards a judgment. Inferential capacity is *a form of expertise* and is separable from other such forms: expertise around *action* or *perception*. Tools, techniques, and practices that foster skilled manipulation of the physical world (e.g. building a dyke) or the registering of information (e.g. measuring water-levels) are *not* part of inferential capacity. Defined as such, the development of inferential capacity can be empirically studied.

Inferential capacity is the *determining capacity* within anticipatory governance. Anticipatory governance is the deployment of capacity through which agents perform *decisions* to *steer* possible futures (Guston, 2014), to imagine and "pre-experience" potential futures to query them and experiment with new strategies (Vervoort and Gupta, 2018). Anticipation readies itself before events occur instead of reacting to the events (Rosen 2012). Addey and Anderson discuss, for example, how modeling ash clouds of volcanic eruption in Iceland rerouted air traffic, instead of the subsequent eruption itself (Addey and Anderson, 2010). An anticipatory stance contrasts itself with reactive evidence-based policymaking: evidence on the past might not capture the future (Saltelli and Giampietro, 2017). The shift from reactive policy-making to anticipation promotes techniques, tools, and practices that sophisticate *inference*. The characteristic representations are uncertainties, scenarios, and forecasts with implications for policies and politics (Jasanoff and Kim 2015; Vermeulen et al., 2013; Hajer and Pelzer 2018). Muiderman et al. (2020) recognize at least four different ends implied by anticipatory governance. First, to assessing futures to infer risks and reduce them. Second, to explore different plausible futures and inferring how one may prepare and adapt as these unfold. Third, to imagine pluralist futures speaking to different societal agents and collectively inferring new, desirable futures. And fourth, inferring how current understandings of futures have (harmful) consequences in the present (Muiderman et al., 2020). For all such ends, *inference* takes center stage. Inferential capacity is what enables the different ends of anticipatory governance, whether it highlights future risks, settles plausible scenarios, decomposes different perspectives on complex futures, or discovers the political implications of present actions.

A further point matters: inferential capacity concerns *group agents*. While organizations lack consciousness and phenomenal states, they do exhibit intentional states such as purposes, goals, and beliefs – they bring about, reduce or avoid consequences to which they infer. The way and degree to which a group has developed its inferential capacity will influence what purposes and goals it can serve and how well-suited its beliefs are. Inferential capacity belongs irreducibly to the group agent: a member of the group can infer things the group cannot *qua* group agent, and the group can infer things the member may not (for philosophical works on group agency and inference cf. Epstein 2015; List, 2018). Inferential capacity at the group level consists of techniques, tools, and practices to serve the different ends of anticipatory governance. For example, the Thai Hydro-Agro Informatics Institute (HAII) that is discussed in a case study below combines systematic observations with axioms encoded in formal theories expressing well-defined concepts to predict risks in the Chao Phraya basin. At the same time, it deploys skilled, intuitive and social practices of imagining within local farmer communities to discern local consequences.

What does it mean to say that inferential capacity develops? On the one hand, a capacity takes shape. On the other hand, something else is shaping the capacity.

### 2.1. What does inferential capacity entail? Resolution, scopes, and modes of inference

There is always a gap between two pieces of information. To infer is to 'jump' from a premise within that information (however shoddy) to an expected possible consequence (however unlikely). Inferential capacity grants access to and refines options for inference. Techniques, tools, and practices change the options for inference. They do so by granting the group agent access to different *resolutions*, different temporal and spatial *scopes*, and different *modes of inference*.

First, a group develops inferential capacity by learning to modulate the resolution of information. By increasing or decreasing the *resolution* of information under group attention, different consequences are coaxed into group awareness. For example, if the Burmese Directorate of Water Improvement and River Systems (DWIR) assesses points of weakness on a particular British-built dyke in Myanmar, in light of concrete, possible future extreme water levels and meandering of the Ayeryawaddy river, the inferred-to consequences are granular and more deterministic, and the tools, techniques, and practices must form in accordance to satisfy the demands of anticipatory governance. If such dykes are to increase preparedness, information must become more granular to fix and modify the dykes in the right places. In contrast, the hydrological model of the Danish Hydrological Institute (DHI) contains no such real-world detail: it simplifies the real world and makes it probabilistic, with less predictive accuracy on the particular case. It promises its users a tractable set of problems to infer upon and applies widely. By adding or losing information, different predictions of different types of consequences appear. Different options for inference become accessible to the group agent. For example, inside a grid cell of the hydrological model there is no further information: the model does not grant access to inferences. Conversely, giving voice to the testimonies of citizens living next to the particular dyke grants access to inferences about the societal consequences of reinforcing the dyke in light of future river

behaviors.

Second, inferential capacity increases options for inference if it affords the manipulation of temporal and spatial *scopes*. If an agent can narrow or widen the temporal or spatial scope, the inference can cover longer or shorter periods or smaller or larger areas. A wider *spatial* scope, for example, enables agents to "zoom out". They can represent the delta as part of an Earth system, granting access to different options for inference. A narrower scope enables, say, an agent to focus on specific expected water flows within a canal. A wider *temporal* scope enables, for example, deltas to be seen as vulnerable to sea-level rise in the year 2100, while a narrower scope allows the forecast of a flood on the basis of upstream measurements. Resolution and scope modulate all information of a given, represented system (Ryan 2007). In choosing a scope and a resolution, the agent determines the information for inference.

The third way inferential capacity improves is by developing a *mode* of inference. A mode of inference occurs through its *procedures* in inference. An introductory logic course will teach that a logician deducts (moving from premises to a necessary consequence), inducts (moving from observations to an uncertain consequence), or abducts (moving from a consequence to the conditions best explaining it). Analogously, for group agents arranged into a practice of inferring with their techniques and tools, the different directions that a procedure can take become salient. A group agent may, for one, infer by using axioms or principles encoding formal theories to express basic concepts (or generate virtual data). An example is a hydrological-mathematical model, and another would be a climate model or a probability distribution to infer risks. A group agent may also deploy a procedure reversing the direction – it may start by collecting pre-formal intuitions and observations to discern basic concepts guiding inference. An example is a master plan for the future adaptation or development of a city or a delta. Another example is a participatory mode of deliberating with citizens about desirable futures, co-creating scenarios as guiding images to inform present policies. A mode of inference generates and modifies options for inference, by modifying steps in its procedures, whether these consist of simple, implicit heuristics or rigorous, explicit formal operations. A mode may require deskwork and computing or conversations in a village square. The mode of inference is the procedure a member of the group agent uses when jumping from one group inference to the next.

**Entrenchment in networks.** Answering the empirical question of *how* inferential capacity develops in a real world setting requires the concept of generative entrenchment (Wimsatt 2007): "a generatively entrenched feature of a structure is one that has many other things depending on it because it has played a role in generating them" (Wimsatt 2007, p.134). Indeed, we see robust multi-scale networks of experts, including scientific networks, influencing policymaking across levels of governance (Haas 1992; Reinicke, 2000; Stone 2002; Betsill., 2004; Biermann 2014; Gupta et al., 2012). These networks are categorized with the concept of "global knowledge networks" (Stone 2002) and they themselves robustly tie to governments, private, and non-governmental agents that operate at many scales (Croxatto et al., 2020; Ottaway, 2001). The robust entrenchment of such networks becomes generative of inferential capacity, which in turn helps further stabilize these networks. In network science terms, these networks provide robust long-range connections between local lattice networks that reinforce each other (Barabasi 2016). The cases that are studied in this article shows how inferential capacity for anticipatory governance depends on entrenched, robust networks, which in turn form through the purposeful activity of agents. The simultaneous networked processes of local lattice and 'global', long-range interactions explain how practices become fixed and conventionalized, while (as we will emphasize in the cases) historical contingencies and strategic choices induce constitutive, normative, and individuating features of different sites.

## 3. Methodology

To understand how networks shape inferential capacity, we have to trace real-world networks. Two different methods, shifting the scope and the resolution, allowed us to see different features of those networks. With one method, we stood, so to speak, on a hilltop observing the landscape – a social network analysis revealing the network topology, relevant communities, and long-range connections. We climbed that hill after we had pursued another method down in the field, observing its 'flora and fauna', seeing how expert agents interacted and depended on each other – a multi-sited ethnography generating information on the agent-level interaction in local lattice networks. The methods, each generative of different types of inferences, complemented and corrected for each other. Neither method gives a complete description by itself, and taken together a different set of questions becomes possible to study and answer. Placing a perspective on the micro-settling of ties in conjunction with a perspective on macroscopic, emergent networks gave us a triangulated and transperspectival view.

The multi-sited ethnography enabled representing the human interactions in the testimonies of respondents (82) and notes. The set was compiled with a snowball sampling method, conducted between April 2016 and September 2018 in Thailand, Myanmar, the Netherlands, the UK, and Denmark. Further Skype interviews took place with respondents in Australia, Japan, and Singapore. The respondents either created, brought, passed on, adjusted, or received expertise on making better inferences.

The ideal study would have gathered data at *every* site of the human contact network to compile the emergent large scale networks. Looking and asking, alas, are not as effective and efficient in compiling a large-scale network, as, say, the automatic registering of phone data. The social network presented here instead describes the burdensome tracing of linkages mentioned or observed in the interviews and observations, and by secondary data obtained from examining prominent documents from all the listed organizations. It resulted in a database with over 400 agents. The nodes in the network are agents. The ties reflect a type of *formal exchange*, of four types. The first type is the platform. Platforms have formal members, an operational office, and function as robust conduits for expertise. The second type of formal exchange is the interstate agreement. In such agreements, states pledge to cooperate on a limited agenda (say, a memorandum of understanding), requiring expertise to implement. The third type of formal exchange is the contract. For example, between state agents and knowledge institutes, NGOs, or the private sector. The fourth type of formal exchange is the cluster of standalone agents making up a larger agent (for example, UNEP and UNOPS are both parts of the UN). We will focus on different *communities* active in both countries. A community is defined here as "a group of nodes that have a higher likelihood of connecting to each other than to nodes from other communities" (Barabasi 2016, p. 322). Our graphs depict communities around a single agent. Its formal exchanges are our proxy for increased likelihood of interaction in the human contact network.

Fig. 1 shows all group agents with robust, long-range exchange: a chaotic, dense set of ties within and between different, overlapping communities. These formal exchanges abstract away the *informal* ones causing them. Using the same data in a differently ordered graph, one can infer what is obvious 'on the

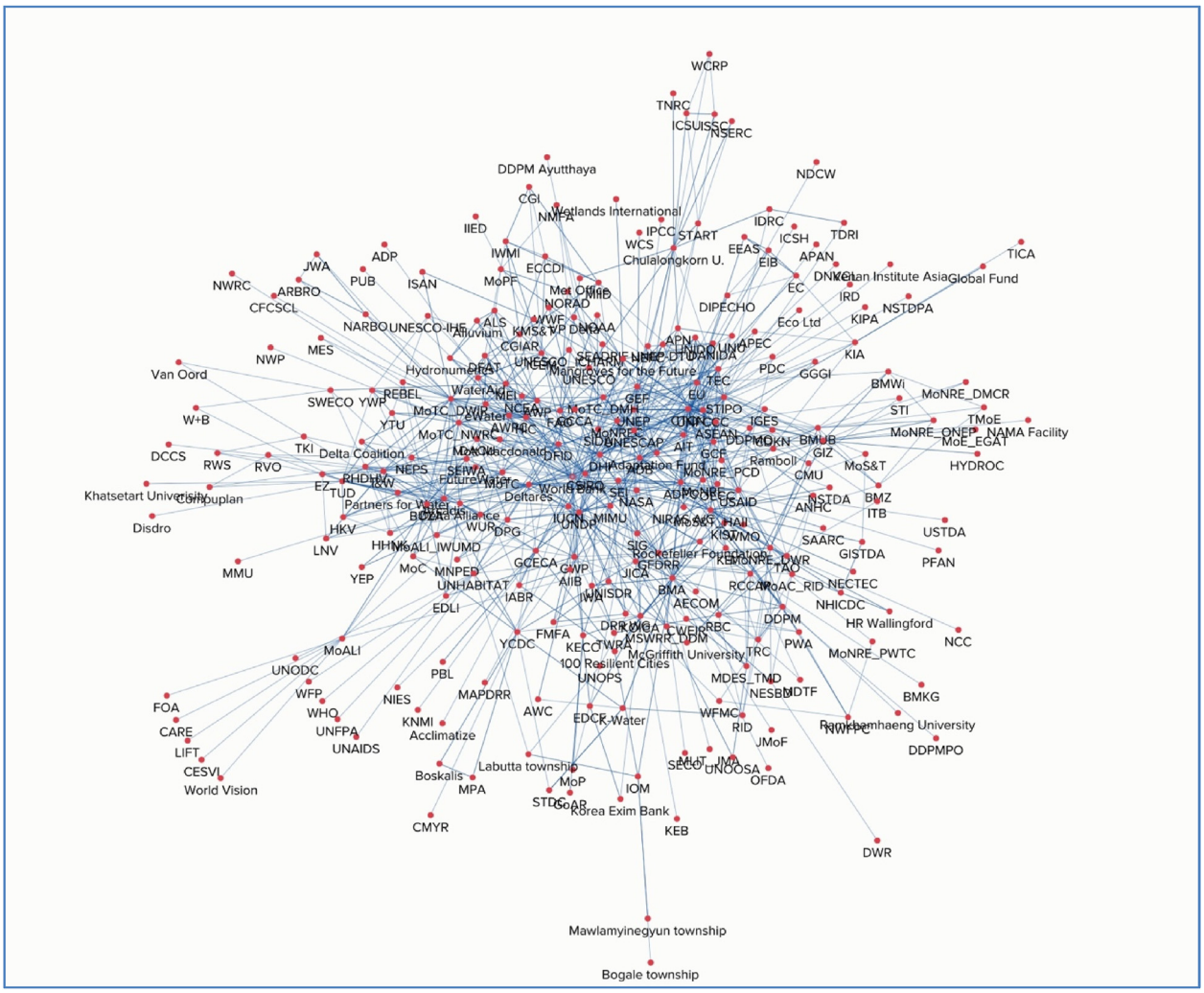


**Fig. 1.** A representation of the global network of agents developing inferential capacity in the Chao Phraya and Ayeyarwady deltas in the period 2016–2018. Source: Authors.

ground': the Ayeryawaddy delta has more ties as destination of expertise and the Chao Phraya delta is a regional hub for exchanges of expertise. Myanmar is for the UN a Least Developed Country (LDC) and informally referred to as a "donor darling"; Thailand is the regional power of mainland Southeast Asia, with headquarters and regional offices for global agents. But ethnographic methods do more than confirm. They add information. For example, on showing the importance of repeated *informal* meet-ups to shape *formal* networks.[1] Taking an anecdote: if a respondent relates of an embassy cocktail party where the ambassador forged a link between a Myanmar politician and an engineer, resulting in a contract for inferring suitable spots for future deep water ports (and subsequent development of inferential capacity), the story helps explain a link. Asking a Dutch engineer where her time went, she answered her job was "all about establishing contacts." As trivial as this sounds, it is indicative of where most of the effort goes: not to evidence-gathering or technical analysis, but to network formation.

All formal exchanges promoted techniques, tools or practices, but not all of them focused on inferential capacity. That filter was supplied by the interviews. To spot diversity within relevant communities, the dataset used labels to differentiate agents, from governments, private sector organizations, intergovernmental organizations, research institutes, knowledge networks, nongovernmental organizations, and local actors of civil society. Each agent either had a headquarter location and/or a regional presence, anchoring the network to geography. Each agent would have a typical scale of operations, from global, regional, national, subnational, urban, to small-scale local. The aims of the activities and the transferred techniques, tools and practices were labeled with UN nomenclature.

Widening the spatial scope to a global scale shows a network of multilevel governance with central hubs and distributed nodes. The temporal scope is limited to the researched period (2016–2018). As a caveat: epistemological and practical limits on discovering ties must qualify the confidence in the map's completeness; our principal aim was to explore the concept of inferential capacity, and we used the empirical data to carve it, and to increase its robustness.

[1] Interview with the project leader of the Integrated Ayeyarwady Delta Strategy (IADS) of Arcadis.

## 4. Results: the development of inferential capacity in the Chao Phraya and Ayeyarwady deltas

Three agents, and their communities (their first-degree ties), leap forward when we observe the development of inferential capacity in Southeast Asia. Looking at them closely tells us about how modes of inference entrench and in what ways they increase options for inference. We look at their histories and backgrounds and see how their strategies explain their position in the network. The first agent is the Dansk Hydraulisk Institut (DHI), active in both river systems. We explore how strategic positioning suits the tools, techniques, and practices that DHI promotes. The second agent is the Hydro Agro Informatics Center (HAII), a department of the Thai Ministry of Science and Technology. We explore how it ingenuously fostered network reciprocity by trading superior inference for dispersed data, building a composite view. HAII thereby gained national and regional importance. The third agent, Arcadis, showed us how a different mode of inference, depending on nation-state backing and buy-in, experienced difficulty in improving inference within a competitive field.

### 4.1. Positioning for network effects

DHI, in 2020, is a market leader in hydrological models. It gained that title by leveraging network effects after strategic positioning. It helps to be early: DHI was founded in 1964 as the "Institute of Water Production" in the Technical University of Denmark. The founders previously worked at Delft Hydraulics. Delft Hydraulics was a Dutch research institute, and it made scale models to infer upon (also in planning the Bangkok harbor). DHI focused instead on mathematical modeling from the start. Their mode of inference imposes a sequence of steps bracketing data as input and creating virtual data as output. Formal theories, encoded by axioms or principles, regiment inference. The DHI models create more options for resolution and spatial scope: the river system can be modeled at small-scale scopes for water flows, larger scopes of river basins, and even (though less reliably) scopes where river basins are connected to regional climate models, themselves downscaled from global circulation models.

Being software, such models would disseminate easily once ICT infrastructure emerged. Delft Hydraulics turned into Deltares (another prominent research institute in the dataset) and moved from scale models to mathematical ones as well. DHI privatized, and it now had a model to sell, opening centers and offices at institutions abroad. In the database, the relevant offices are in Copenhagen at UNEP, in Singapore, and at the Asian Institute of Technology (AIT) in Bangkok. Deltares is still DHI's competitor in Thailand and Myanmar, and has offices in Singapore and Indonesia, but it is not a significant market player and has no offices in Bangkok or Yangon.

Both the network representation (Fig. 2) and the interviews suggest that DHI has a competitive advantage in Southeast Asia. In 2001, the United Nations sought a partnership to develop expertise on water (the UNEP-DHI Partnership), giving DHI global reach in development cooperation. Starting small, with one director and a handful of staff, UNEP later hired more DHI staff. It reflected a shift: from the 1960s until the 1990s development cooperation was about implementing engineering 'solutions' in the form of 'hardware'. Hardware was not DHI's route:

> "If you install a water pipe and leave it there, in 6 months something needs to be changed and no one knows how to do it, very much like the type of World Bank intervention."[2]

DHI instead pursued developing and selling its tool for inference, and did so by networking and partnering with other institutions and by pursuing private sector strategies, while occupying strategic points in global and regional networks. The DHI office at the Asian Institute of Technology (AIT) in Bangkok was chosen, since AIT was *the* regional academic hub for water expertise. Training students and granting them free use of DHI models was a smart strategy. Thailand's fractured water governance made (and to an extent still makes) use of different hydrological and hydraulic models, but AIT gave DHI a strong market position in Southeast Asia. The Thai Water Resources Department (WRD) lead hydrological modeler said:

> "We use models like Wallingford [from the UK] as well, and there are still others. And most hydrological models are just as good as the next. But when we hire people, our staff already understand [the DHI models]. It is expensive to retrain them and inconvenient."[3]

Once employed, AIT students would press their employers to buy a license. Different employers faced the same situation. It converged governance to use of this model, improving the network position of DHI.

DHI also builds inferential capacity directly in Thailand. For example, Bangkok floods, and DHI made a contract with the Bangkok Metropolitan Administration (BMA) to supply software and train its staff. Bangkok, before the 20th century, was an aquatic city. Traffic and trade happened through a vast network of canals in the Chao Phraya delta. Roads were scarce to non-existent. Respondents attribute the city's persistent floods to the rapid, unplanned growth after World War II, in combination with upstream deforestation, agricultural practices, and mismanagement and corruption around hydro dams.[4] For the BMA, DHI delivers flood forecasting and hydrological modeling.[5] This enables foresight on unexperienced harms in the floodplain and suggests where improvement is possible. Such inferences shift Thai attention away from reacting with grey infrastructure on vulnerable spots *of the past*.

DHI acted in Myanmar as well. The Burmese military junta closed the technical universities in 1988. Inferential capacity on the expected behavior of the river system, developed by the British and Burmese civil service, had decayed. DHI has a contract with the World Bank to help set up the Myanmar Hydro Informatics Center (HIC), part of the 100-million-dollar Ayeyarwady Integrated River Basin Management project (AIRBM), administered by the Burmese National Water Resources Committee (NWRC) and the Directorate of Water Resources and Improvement of River Systems (DWIR). The network of the Myanmar HIC (Fig. 3) binds different ministries, domestic and foreign, through its formal exchanges, but develops inferential capacity via private sector agents and research institutes. With so many fish in the pond, agents compete and coordinate to sustain the attention of the Myanmar government. DHI thus embedded its software within the Dutch-produced Integrated Ayeyarwady Delta Strategy (IADS). In modeling the Ayeyarwady river system, DHI cooperates with Arcadis and Deltares in taking Delft2D modeled data and using it as input for DHI hydrodynamic and morphological models. Working with consultancy firm Mott MacDonald, DHI builds a decision-support system and trains Burmese staff in hydrological modeling. The modeling is entrenched into the institutional design (see the discussion section).

[2] Interview programme officer UNEP-DHI, UN City, Denmark, 2017.

[3] Interview with chief hydrological modeler at the Water Resources Department, April 2017.

[4] Interview BMA sewerage and drainage department, October 2016.

[5] Interview RID, October 2016; interview Danny Marks, October 2016.

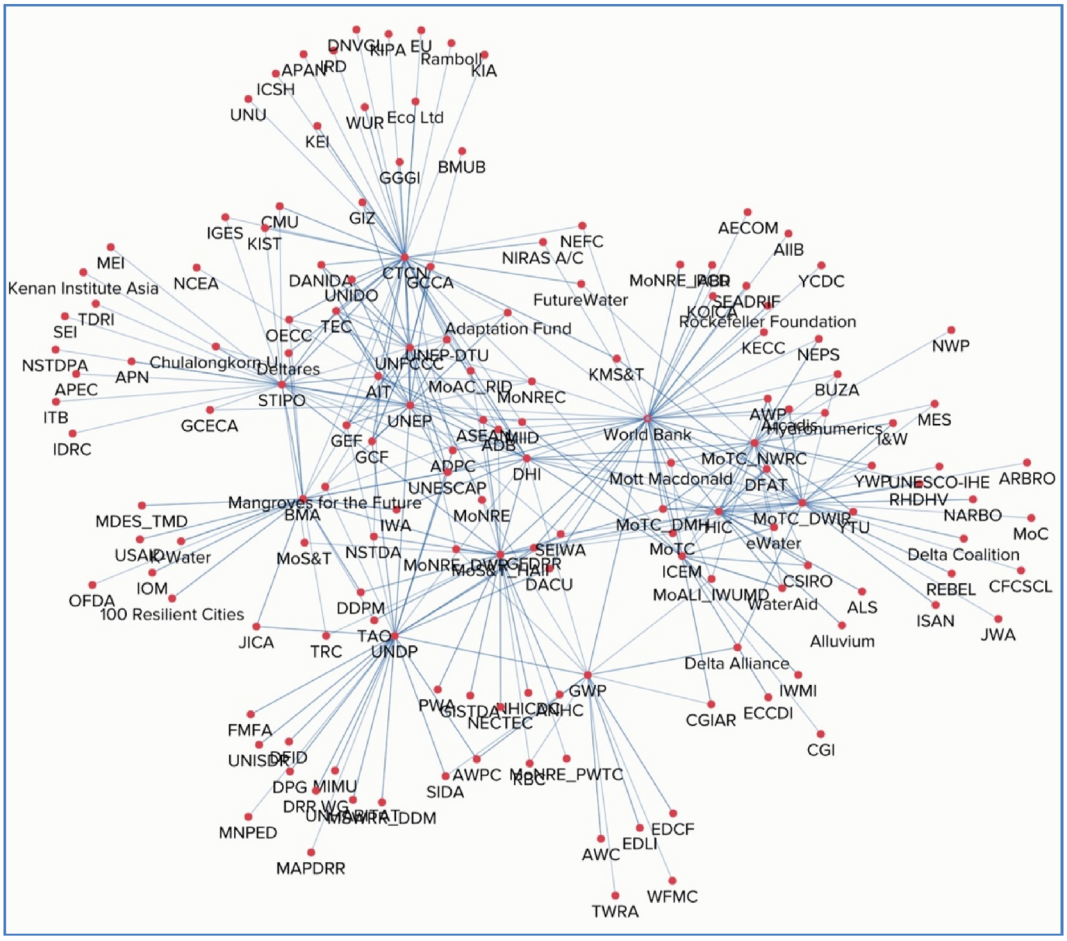


**Fig. 2.** The Danish Hydraulic Institute (DHI) and its community. Source: Authors.

### 4.2. Fostering reciprocity

The next agent is the Hydro Agro Informatics Institute (HAII), whose community is shown in Fig. 4. This agent allows us to show most clearly that inferential capacity is a *network* competence. Network reciprocity resulted in systemic improvement, increasing options for inference for spatial scope and resolution of information for the governance of the Chao Phraya river system. HAII falls under the Thai Ministry of Science and Technology. Today it has a hub position in Thailand, and it has expanded to Myanmar and other Southeast Asian countries. HAII has dense ties with 26 Thai water governance institutions and has ties to a subset of thousands of Thai rural cooperatives. HAII also connects to regional agents such as ASEAN or the Asian Disaster Preparedness Centre (ADPC) and global research institutes, such as the Stockholm Environmental Institute, NASA, USAID, or Deltares. HAII policy analysts and data scientists work with complex data analysis methods, developing the inferential capacity of a fractured water governance of Thailand.

HAII originated in the mid-1990s and was set up after one of Bangkok's floods in the 1990s by King Rama IX. Rama IX ruled for 70 years and led, in symbolism and to an extent in practice, Thailand's development, including in water governance. HAII was designed with the help of the U.S. Massachusetts Institute of Technology (MIT). The King was born in Cambridge, Massachusetts in 1927. His father, Mahidol Songkla (known as the father of modern medicine and public health in Thailand) studied at Harvard and MIT. The family maintained these ties, easing the transfer of techniques and tools to HAII. The King had value-related reasons and technology-related reasons to develop HAII. First, the King became disappointed with the Western development ideology he himself had first facilitated for World Bank loans. On the technique front, after floods, the Thai had focused on “grey” infrastructure tied to an economic development agenda. HAII was a strong departure from these practices. It was designed to develop in tandem with the emergent ICT networks, and focused on strengthening the inferential capacity of Thai flood and water management.

Such progress mattered. Before HAII was set up, Thailand's many governments for water management, six of which sizeable, did not cooperate. According to HAII's director, Thai water governance was notorious for lack of coordination, evasion of responsibility, and presence of conflict, resulting in preventable floods. These institutions had imperfect data (e.g. on paper, no dates, or incomplete). HAII spotted an opportunity here. It could remove the incongruence between data sources distributed throughout Thailand's water governance institutions, improving the data's quality, and disseminating it back to the separate organizations. In this way, it increased its own capacity, with increased scope and resolution of information. It relied less on forecasts with large temporal scopes, and used mathematical combinatorial methods to combine data sources to infer upon. HAII improved all agents' capacity, but mostly its own and its position in the network. By first *giving* something, it fostered network reciprocity, receiving more data.

Since HAII's origin lies with the King, this gives the institute a distinct Thai influence. King Rama IX, an institution in itself, had a

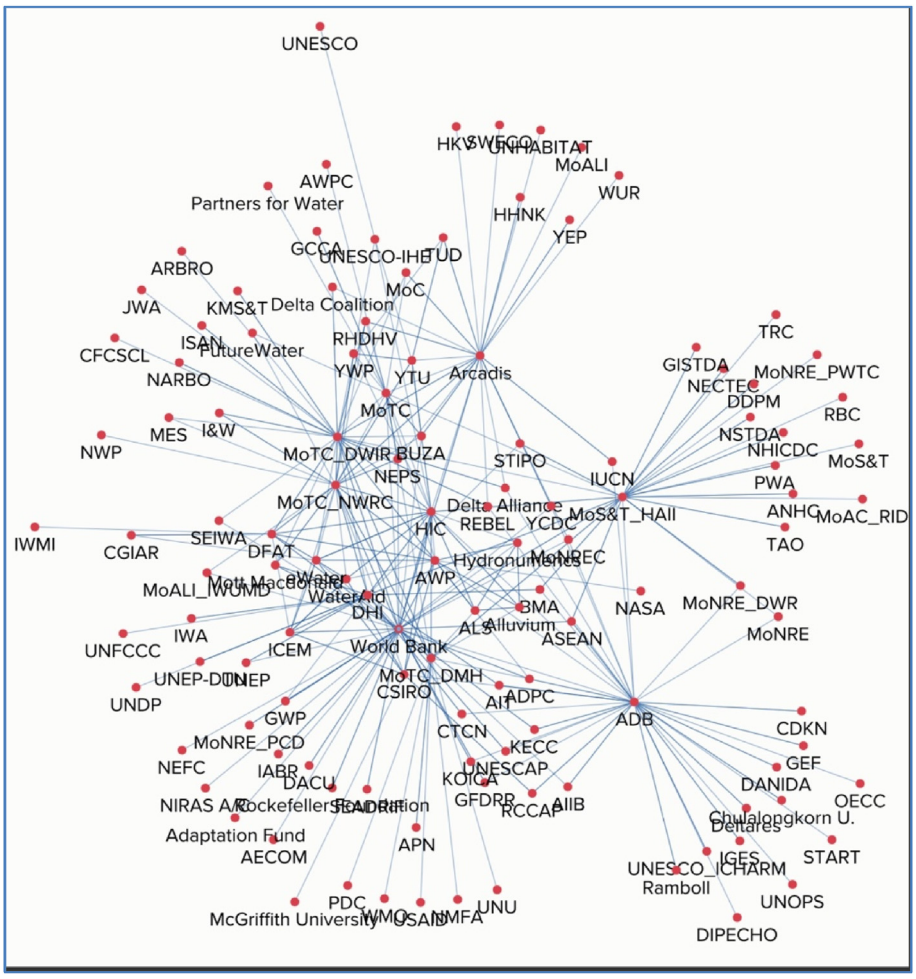


**Fig. 3.** The Myanmar Hydro Informatics Center (HIC) and its community. Source: Authors.[61].

tremendous influence in shaping Thailand's position in global networks on water knowledge. The Thai King ensured that the institutional design of HAII reflected the Buddhist doctrine he promoted throughout Thai society (the *Sufficiency Economy*, SE), a way of collective living and public administration (Hogendoorn et al., 2018). The SE doctrine, for example, pushes people to develop within their means (instead of taking on loans). The King's fund increased public investments in water management at the local level of self-governing rural cooperatives, tying them to national institutions in the capital of Bangkok. HAII ties to rural, SE-subsidized cooperatives, which strengthens local capacity. Employing its reciprocity-seeking and incongruence-decreasing network strategy, HAII says it obtains local expertise and returns expertise.[7] HAII also trains policy makers throughout Thailand in workshops, and after the 2011 floods, HAII set up a mobile ICT fleet, equipping trucks with data centers for quick monitoring and analysis of flooded regions.[8] HAII, in line with the development philosophy promoted by the king (the Buddhist inspired Sufficiency Economy), focused its effort to make the best use of presently available resources and to remove 'disquiet' from the network of inference. The former director of HAII dismissed the use of global and downscaled circulation models on the impacts of climate change; such a large scope is incongruent with the practices that gave HAII its network position — by a focus on present, 'local' resources to infer future consequences.

HAII's strategy resulted in a hub position within Thai water- and climate governance. Its influence rises in the Southeast Asian region. It is setting up a planned total of fourteen HICs in parts of Thailand and elsewhere in Southeast Asia, including the HIC in Myanmar. By helping to set up sister organizations, it is replicating and entrenching its inferential capacity. The centers are set up in communities around the regional intergovernmental organization ASEAN or, as in Myanmar, the World Bank.

### 4.3. Master planning

The third agent is Arcadis, a Dutch engineering company (whose community is shown in Fig. 5). It operates in Myanmar and in Thailand. Though in tried, in Thailand it does not contribute to inferential capacity for anticipatory governance (it has clients in construction). Arcadis co-organized "Water Missions" with the Dutch embassy to sell expertise on Water, Sanitation and Hygiene (WASH), hydrology, land subsidence, and flood management, but failed to garner interest. In Myanmar, it had more success with its Integrated Ayeryawaddy Delta Strategy, though it did not achieve a systemic entrenchment of inferential capacity as DHI or HAII did during the observed period. Unlike our other two agents, the mode of inference this agent promoted focused on moving from pre-

[7] Interview former HAII director Dr. Royol Chitradon, April 2017.

[8] See http://www.activepower.com/en-GB/documents/3620/thailand-ministry-case-study.

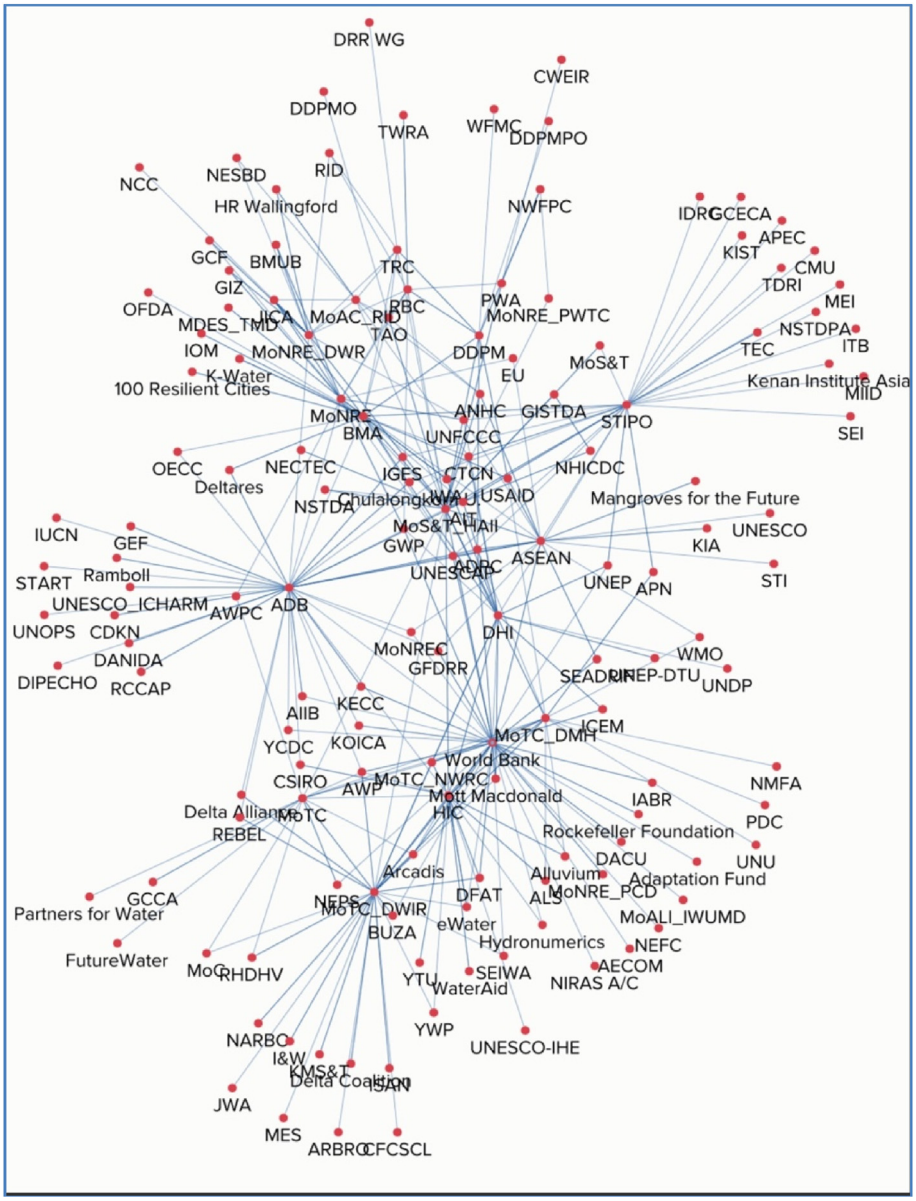


**Fig. 4.** The Hydro Agro Informatics Institute (HAII) and its community of agents. Source: Authors.

formal intuitions to basic concepts. Those concepts were pieced together into master plans with a large spatial and temporal scope (the 'delta master plan'), but with a very low informational resolution. The delta plan first used the colonial era, administrative border of the Ayeryawaddy delta. It would later incorporate the adjacent deltaic area around Yangon. The plans tied this area to climate and economic scenarios, making the delta both a standalone system and part of larger Earth systems. An absence of government data on the river system in Myanmar meant the resolution of information was much lower than expected.

Arcadis cooperates with the World Bank and its AIRBM project, already mentioned above (first community). Arcadis is also part of the Dutch Delta Alliance, a knowledge network tying Dutch research institutes such as Deltares, Wageningen University and Delft University of Technology. Arcadis has close ties to the Dutch Ministry of Infrastructure and the Environment (I&W) and the Dutch Ministry of Foreign Affairs (BUZA), and set up Memoranda of Understandings with Burmese ministries. The subsidized national approach ensures a coalition with competing, locally well-connected Dutch engineering companies in Myanmar such as Royal Haskoning/DHV.

Arcadis' efforts teach us about nation-state backed efforts in developing inferential capacity. In 2008 Cyclone Nargis devastated the Ayeyarwady delta with more than 100,000 casualties, and forced the Military to let in foreign aid. It proved to be the thin edge of the wedge: Nargis provided the opportunity, its Least Developed Country-status signaled a high need, and its geopolitical position between China and India meant entrenchment was urgent. Countries with an international development cooperation (IDC)

[6] Fig. 3 represents the community around the Myanmar HIC. DHI and Mott Macdonald develop inferential capacity within the HIC office in Yangon, with social values and norms translated into algorithms developed in UNESCO-IHE in the Netherlands and HAII in Thailand. Links from Yangon Technical University and the Asian Institute of Technology show local routes of sourcing for modeling expertise. The linkages with Australian agents show the failed bid for a first modeling of the Ayeyarwady river system's hydrology, discussed below for the third community.

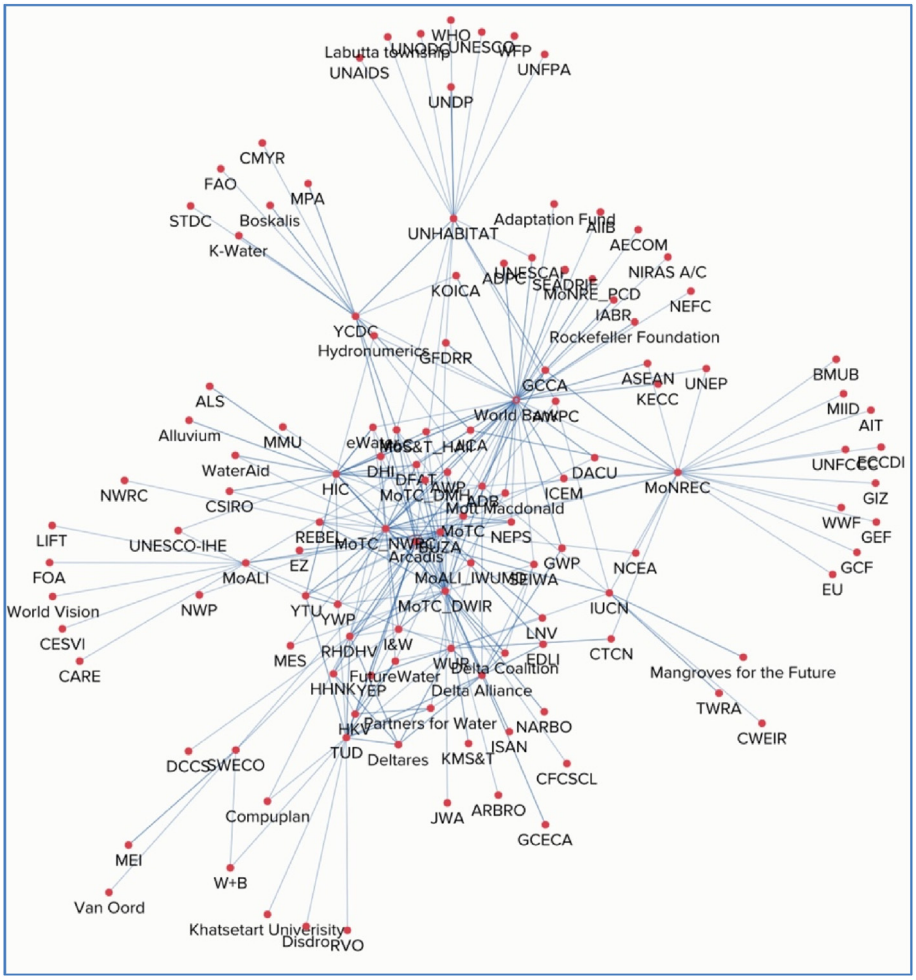


**Fig. 5.** Foreign competitions, as seen from the Arcadis community. Source: Authors.

tradition — e.g., Australia, the U.S., the Nordic countries, Japan, South Korea, and Thailand — entered and occupied niches. The Nordic countries, for example, focused their efforts on improving human rights, gender, and education. Dutch agents on profit/purpose-driven efforts on water and food, and Australian agents on droughts and water. Other nations focused on urban planning projects and infrastructure. Thailand was already well-connected to global agents, such as other nation states and intergovernmental organizations (IGOs), and provided a hub-function for Myanmar. Bangkok hosts IGOs as a regional seat (e.g., the UN, ADB, ADPC, and World Bank). Some ties in the development cooperation sector, such as with the German GIZ, go back decades to when it was a developing nation. As the rise of HAII's HIC involvement shows, Thailand is a direct influence in Myanmar as well. The first expertise that was developed in Myanmar focused on improving responses for recovery and disaster risk reduction (interview ADPC Myanmar). But as time went on, a political project of developing the country intertwined with the need for an anticipatory governance of the river system that provides the lifeline of the country.

The Ayeyarwady river defines Myanmar. It runs from the mountainous Northern border to the Southern delta on the Andaman Sea. It was the last free-flowing major river on Earth (no major infrastructure, next to no governance). Burmese data on the river's behavior was scant and inferential capacity undeveloped. The World Bank-led programs AIRBM (planning for the basin) and the associated Arcadis' IADS delta master plan intended to change this. Dutch engineering firms have a long presence in the country. The Dutch engineering firm Royal Haskoning was active in Myanmar before it became a hermit state in 1988. Many now elderly engineers in Myanmar were trained in Delft. Arcadis tapped into these dormant networks, and set up formal exchanges with Myanmar's officials and Dutch ministries, who signed Memoranda of Understanding with Myanmar. The Myanmar Ministry of Transport settled one MoU in 2013 between the Dutch Ministry of I&W, for an integrated water resource management study. This would become the basis of a national plan for Myanmar. And it settled one in 2015 with the Dutch Ministry of Foreign Affairs to stimulate business in the "water—food nexus." Another formal anchoring of this network occurred by setting up a tripartite Australian-Dutch-WB coordination body and settling Terms of Reference. The Australian Department of Foreign Affairs (DFAT) and the Dutch ministries of Foreign Affairs (BUZA) and Infrastructure and the Environment (I&W) tie to the Burmese Directorate of Water Improvement and River Systems (DWIR), the Ministry of Transport (MoTC) and the Ministry of Agriculture, Livestock and Irrigation (MoALI). DFAT backed its research institutes and private companies through the Australian Water Partnership (AWP) with eight million Australian dollars in funding, focusing on hydrological models.[9] The joint effort between the Dutch and Australians was a marriage of

[9] Interview Arcadis with Tanya Huizer, June 2018.

convenience. The senior diplomat that founded a Dutch embassy in Yangon in 2008 said: "the Australians do not have any water knowledge unless we [the Dutch] gave it to them. They are a country of droughts."[10] Despite high-level delegations, and much effort, both countries lost the bid. They lost the World Bank tender in 2018 to the Danish company DHI, whose strategy of positioning for network effects was explained above. Not everything was lost, however. The coordinator of the AIRBM project for the AWP working with DWIR, explained: "there's a division of labor for additional modeling. The Australians will likely model the River Basin, and the Dutch will model the IADS project."[11]

DHI's actions reflect a long-term strategy that does not depend on, say, the Danish government. Arcadis could not emulate this, relying on the commitment of the Dutch government. Unlike other IDC countries, the Dutch government has a small development cooperation budget and invests in small projects. The Dutch doctrine is "aid through trade." This doctrine also frustrated a Dutch diplomat. For every workshop or small project with buy-in from the Burmese government and Dutch engineering firms, the diplomat needed permission from Dutch ministries. The ensuing bureaucracy took months. This delay would irk the Burmese engineers and civil servants, who – with all their suitors – could switch their attention to countries with larger, long-term fixed, and freer-to-spend budgets, such as Japan and Australia.[12]

Whereas DHI and HAII strategically entrenched other agents in their capacity to infer, the Dutch government's strategy rested on signing MoUs and having the Myanmar or Thai government to believe a narrative: Dutch expertise on water governance is the best of the world, proved by a perfected control of their own delta.[13] That polished narrative reflects that The Netherlands sees expertise on water as a 'top sector' export product. Indeed, the Netherlands developed special institutions for the global dissemination of water expertise, including a Special Envoy with an Office in The Hague who travels the globe to foster formal exchanges. The Dutch government helps Dutch firms to link to the UN system or the EU, with Dutch businesses harmonizing the water agenda with global agendas on dealing with climate change and sustainable development. Research institutes like Wageningen University, Delft University of Technology, and Deltares form knowledge networks with engineering firms and ministries (an example is the "Delta Alliance")

Despite such impressive coalitions, two difficulties arose for Arcadis in the Ayeyarwady delta. First, the lack of quality data and water governance institutions implied that there was no basis for inference. Lack of plausible data makes promises of comprehensive "delta planning" verge on misrepresenting matters – the options for inference in terms of resolution were severely limited. A case in point is the Delta Atlas, the product of assembling existing data about the Ayeyarwady delta so that agents would have something to infer upon, whether through pre-formal intuition or formal models. The Dutch embassy in Myanmar and the lead of the IADS project Arcadis shared their Delta Atlas, but with the cautionary remarks. The Delta Atlas has a glossy presentation with graphics, basic concepts, and maps. It provides the first overview of the available data in the delta region. As such, it is an important document and a first step in the build-up of inferential capacity. But the assembled Burmese data is patchy and of unreliable quality, supporting nothing but the vaguest of long-term plans. The Atlas also highlighted how these efforts face difficulty in hierarchical bureaucracy. One of the Delta Atlas's authors reflects: "even if we wanted to share data within our own consortium, we had to wait weeks, if not longer, for Burmese permission."[14] A lack of good data, of institutional capacities, and of government transparency, compromised the initial IADS ambition, but its main (and significant) contribution to the development of inferential capacity is the registering of ignorance and political intransigence.

The second difficulty for Arcadis followed a shift of focus. The Ayeryawaddy delta had attracted government attention because of cyclone Nargis. But it is large, agrarian, and *poor*. Right next to it lies fast-growing Yangon, the nation's main city. The Ayerywaddy delta decreased in salience as object to infer upon, as the attention of the Myanmar government shifted to Yangon. Population models suggest it will double in size within ten years from 2018.[15] Different Asian countries worked on Special Economic Zones, with Japan and Korea planning a new city on the Southern bank of the Yangon river, a distributary of the Ayeyarwady. For this, the Japanese development agency JICA finished an ambitious urban plan for the Yangon City Development Committee (YCDC). The Korean Exim bank invests in Yangon infrastructure, such as big bridges across the river, with the Korean development agency KOICA involved. The British Department for International Development planned a renovation and expansion of Yangon's colonial-era sewerage system. In short, the urban concept started to displaced the delta concept as a large-scope object for inference, even if the geophysical terrain remained the same. The Dutch government refocused its strategy to water-related projects in the Yangon Region. Urban projects, such as drinking water provision and sluices, offered better prospects.

## 5. Discussion: strategic and historical entrenchment of modes of inference

> *"Westerners clique together, even if they share interests with Koreans or Japanese, because they are* likeminded. *Western engineers think inductively […]. East Asians think deductively [and] work backwards from their conclusion, figuring out what they will need to find out. They say: here we must place a bridge. And then they figure out what they need to know to build it. Westerners first study and analyze and then infer what they need. They might conclude they want a bridge, but they might not.*"- Director of the Korean International Cooperation Agency Yangon[16]

As informal exchanges in the human contact network settle into formal, more robust exchanges, inferential capacity can entrench and develop itself and shape anticipatory governance. The settled, institutionalized tools, techniques, and practices have become generative of the inferences of different group agents in governing.

Such entrenchment itself is a goal. Agents make strategic choices to entrench their tool and techniques and settle a 'germline' to generate inferences within anticipatory governance. Such germlines always find that they are not the first entry: history has already settled techniques, tools, and practices within institutions. A densely connected lattice of local ties, grown over decades or even centuries, tends to give assumptions and procedural commitments a fixed normative status (Wimsatt 2007). As such, the presence or absence of pre-existing inferential capacity eases

[10] Interview with Carola Baller, first envoy of the Dutch Ministry of Foreign Affairs to Myanmar who set up the Dutch embassy in Yangon, March 2018.
[11] Interview with Tarek Ketelsen, river basin planning advisor AIRBM project, October 2017.
[12] Interview with Carola Baller, first envoy of the Dutch Ministry of Foreign Affairs to Myanmar, March 2018.
[13] Interview with Johannes de Groot at Arcadis Yangon, October 2017.
[14] Interview with Johannes de Groot at Arcadis Yangon, October 2017.
[15] Interview YCDC, July 2018.
[16] Interview KOICA July 2018.

adoption *if* assumptions fit, but are resisted more strongly if they don't, since they would unsettle many inferred consequences and their settled policies.

**Strategic choices in entrenchment.** Inference is never value free. Values shape attention, and thus anchor knowledge. Sometimes values are deliberately entrenched with the tools, techniques and practices. Myanmar's Hydro Informatics Center embedded values in its mode of inference and made their deployment part of its institutional design. Its director was a self-described "product" as much of Myanmar as of the Netherlands, trained in exile from the military junta at the hydrological and UN embedded research institute UNESCO-IHE in the Netherlands. She learned at UNESCO-IHE how models could be linked with commitments to procedures favoring the environment and social justice – a model run would require, for example, local knowledge of citizens: "My purpose is to clean up this [water] world, with a triple bottom line: environmentally sustainable, economically viable, and socially inclusive."[17] This entrenchment via software ensures that the HIC must use procedures running counter to those of the engineers of the military regime. In a similar vein, the director entrenched these modeling practices into law, by helping to draft the first comprehensive water law in Myanmar. This law entrenches a practiced mode of inference into the Burmese climate adaptation and water governance policies, into its top-down hierarchical policy practices. The director calls it a "rebellious vision."[18]

Other efforts to entrench a mode of inference leveraged the traits of networks. The Danish Hydrological Institute and the Thai Hydro-Agro Informatics Institute were the clearest examples.[19] For HAII, networking was part of its institutional design: it explicitly aimed to make itself an obligatory passage point and settle a network in a fractured water governance. Fostering network reciprocity by *giving* the use of better tools, techniques, and practices to each organization in water governance, it entrenched itself into a hub position – entrenching its modes of inference in the governance system. DHI succeeded likewise through network effects, but it *positioned* itself for exposure first: DHI positioned its offices in sites where highly networked organizations were located (e.g. UNEP and the Asian Institute of Technology). From there, it counted on high switching costs and network effects. For example, it supplied universities with free software, and students preferred not to retrain when employed. Such networking strategies are not dependent on one thing succeeding, but build redundancy in linkages to reap the opportunities they themselves create. Recall, for Arcadis selling water governance expertise in Thailand proved too difficult.[20] In the case of DHI, a long-term presence and a wily, patient network-oriented strategy paid off. Actors promoting master planning provide a contrast. Such plans are one-shot plans with top-down support, with a spatial scope that includes the delta region, and with a temporal scope for different scenarios going many decades into the future. In the cases studied in our research, such plans include, besides the Dutch-Australian master-planning methods for Myanmar, the delta planning methods to protect Bangkok against floods and subsidence. The activation of tools, techniques, and practices was short-lived, as plans were reliant on long-term buy-in from short-lived coalitions of agents. To sell master planning, ironically, one needs everything to work according to plan.

**Histories.** Thailand and Myanmar's fates both changed radically in the 19th century. It is salient that this occurred in part on account of mismatching geographical, intuitive concepts, altering the resolution of inference: the colonial British empire in neighboring Bengal inferred from the concept of a hard line as a border, a foreign concept to Burmese or Siamese Kings, who reasoned from permeable, spheres of influence of the Southeast Asian city state system. The Burmese King, feeling within his right, provoked the British into invading Burma, while the British mistakenly cut off part of Siam in mappings, since the Mekong river was seen as a hard and convenient border with French Indochine, changing Siam into a neutral buffer zone (Suárez 1999).

Thailand and Myanmar, neighboring countries, took different paths in colonial times. From the 14th century, the Siamese had an elite-led, administrative class governing the waters for trade and agriculture, sometimes inviting foreign experts to build capacity (Baker et al., 2005). Thailand maintained a sophisticated bureaucracy around living with water, developing their own basic concepts, and their own techniques, tools, and practices of inference. Thailand also maintained global ties with foreign experts to learn. The Royal Irrigation Department, for example, which today manages many hydro dams, was founded more than one century ago and led by a Dutch irrigation engineer Homan van der Heide, who promoted planning methods for irrigation canals in the delta (Ten Brummelhuis, 2005). Yet Thailand maintained its *sui generis* inferential capacity and resisted outside influence[21] (Hogendoorn et al., 2018). Even Van der Heide resigned in frustration. During Thailand's economic rise, World Bank programs and U.S. and Japanese expertise changed policies and society. Unsettling, external reforms were however met by intact Thai institutions with protectionist laws and requiring Thai partners for foreign companies, and as an "Asian Tiger," Thailand's economic improving status decreased donor influence.

Myanmar is a contrasting case. Myanmar (then Burma) was part of the British empire since 1885. It became an autocratic system in the 1960s. The 20th century removed most of the Burmese institutional capacity. After British imperial rule, a class of Oxbridge trained Burmese elites tried a democratic rule not aligned with either the Soviet Union or the capitalist West, but failed, due to cascading effects of the rise of Mao in neighboring China. The military took over, responding to external turmoil and internal unrest. Fearing student revolts, it closed the technical universities (Walton, 2016; Myint-U, 2008). Expertise withered. Unlike Thailand, Myanmar stunted its own development of inferential capacity before 2008. Cyclone Nargis disaster forced the military to reopen the country to a globalized world. We should understand the development of inferential capacity in Myanmar against this background. A sudden influx of expertise occurred alongside donor-contributions. The abundance of projects, workshops, and plans urged foreign agents to harmonize efforts, but also put them into competition for scarce government attention[22]: as technical training resumed only after 2008, the government has too few experts. Burmese respondents either jest or complain: attending workshops, the job suffers.[23] Agents compete for their attention.

Dutch delta planners proved less conscious of the values at the root of their knowledge. For example, delta planners in Thailand and Myanmar promoted modes of inference around probable or

[17] Interview Dr. Khi Ni Ni Thein, June 2018.

[18] Interview Dr. Khi Ni Ni Thein, June 2018; interview project leader AIRBM project component 1 at DWIR, June 2018.

[19] Interview modeling engineer Dunyarit Homnan of the Thai Water Resources Department, October 2016; interview DHI's sales manager at the Asian Institute of Technology, October 2016.

[20] Interview Arcadis Thailand, April 2017; Dutch embassy Bangkok, October 2016.

[21] Interview Arcadis Thailand with Anurath Kochea, October 2016; April 2017.

[22] Interview KOICA July 2018; interview HIC July 2018; interview WWF Myanmar October 2018.

[23] Interview YCDC Urban planning department June 2018; interview Project leads AIRBM components 1 and 3 at DWIR, June 2018; interview Arcadis, June 2018.

improbable risks under different plausible scenarios with a large spatial and temporal scope. Such futures have easily inferred political consequences: it assumes control/economic emancipation of the delta region (as was indeed the case in the Dutch delta). In contrast, the Thai Hydro-Agro Informatics Institute is focused on removing frictions within a network of organizations by improving the ability to manipulate the resolution of mutually available data and build a composite spatial scope, but its focus was on the present state of the system to *favor* a future well-governed system – anticipation not through prediction, but through preparedness. King Rama IX shaped this institution's design, according to explicit governing doctrines cohering with Theravada Buddhism, just as Dutch delta planning developed within the confines of a local-historical political doctrine with Protestant Christian elements (Hogendoorn et al., 2018).

This shaping of the modern territory through foreign mappers and the subsequent historical trajectories illustrate a principle of entrenchment: what settled a long time ago, will exert force on inference within a system (Wimsatt 2007). Rebuilding the foundations is unwise and difficult: in Myanmar, colonialism 'brought the house down' doing so, and the present approach to regain inference from foreign basic concepts is ambiguous in its normative, and uncertain in its political implications. In Thailand, the difficulty of fitting the foundations makes grand ambitions from foreign pre-formal, intuitive basic concepts fail, leading successful agents (rightly) to patch less fundamental problems.

## 6. Conclusions

The past decades saw rising awareness of the vast amount of causal links between different systems on Earth. Our knowledge of these links is incomplete, uncertain, and perspectival, but as it grows, so does the ability to govern across scales in anticipation.

Our exploration of inferential capacity is a proof of concept. The techniques, tools, and practices that increase options for inference for group agents affords an empirical study of a world learning to anticipate the Earth systems on which it depends. Though we focused on technical topics, such as inference about climatic or hydrological systems or on exploring plausible scenarios (where increasingly mathematical models express virtual data to infer upon), that does not mean that inferential capacity always sophisticates by taking a rationalist, formal shape. Modes of inference also promulgate in anticipatory governance that run from pre-formal intuitions to basic concepts, where often implicit rules of inference reshape options for inference. Indeed, in our research we noted how agents deploy and entrench modes of inference by arranging techniques, tools, and practices into procedures where pre-formal intuitions (e.g. societal values; farmers' experience; imagined economic futures) were followed by basic governing concepts (legal concept in the Myanmar Water Law; the Sufficiency Economy doctrine; delta master plans).

Other researchers might catalogue the development of inferential capacity in other areas of governance or places on Earth. For example, skilled network analysts may prod much deeper into the topological and structural features of such networks. And trained historians or anthropologists can study with far more depth and empathy the historical and contingent reasons behind a local site's entrenched particular inferential capacities – there is no such thing as a one-size-fits-all approach. Both such advances in understanding would ease the shaping of anticipatory governance of the Earth's systems.

## CRediT authorship contribution statement

The first author, **Daniel Hogendoorn,** was responsible for Conceptualization, Data curation, Analysis, Investigation, Methodology, writing original draft, review & editing. The second author, **Lucas Somavilla Croxatto**, was responsible for Data curation, Investigation, Visualization, Methodology, and editing. The third author,**Arthur C. Petersen**, was responsible for Project administration, supervision, and editing.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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