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Tides of Time: The Dutch Delta Works as Time-Mediating Climate Adaptation Infrastructure

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Abstract
The relationship between infrastructure, climate change and time is a crucial but often misunderstood element of climate policy. This article argues that climate adaptation infrastructures mediate between different temporal regimes and can even be said to generate temporal regimes themselves. By examining the development of the Dutch Delta Works, a set of infrastructures initiated after the 1953 North Sea floods that killed more than 1,800 people, the article reconceptualizes the development from the response to the 1953 disaster to its current relationship with the consequences of climate change, in particular rising sea levels, river water inflows and weather fluctuations such as increased rainfall. By situating the development of the Delta Works in relation to *Kairos*, a period of transition and transformation, rather than *Krisis* as a response to an immediate disaster, the analysis presents a multifaceted perspective on the relationship between infrastructures, time and temporality. Developing the notion of infrastructural compromises to describe how infrastructures connect to and mediate between different temporal regimes, the analysis examines four episodes, each of which involves a different relationship to time and exemplifies different compromises between temporal regimes. As infrastructure development will be of paramount importance for the development and implementation of climate adaptation policies, it is crucial to arrive at a refined understanding of the relationship between infrastructure and time. A heterogeneous conception of time and temporality is needed to do justice to the mediating role of infrastructures in all these issues and the trade-offs that result from this interaction.

Keywords
climate change; infrastructure; time; crisis; climate adaptation; compromise.

1. Unfolding Climate Infrastructures

Waterloopbos, literally "Watercourse Forest", was an open-air laboratory located in a polder forest in the Noordoostpolder in Flevoland, the Netherlands. In the 1950s, it served as a test site for Waterloopkundig Laboratorium de Voorst, where large-scale models were built for the development of waterworks, considered necessary after the 1953 North Sea flood in the southwest of the Netherlands, which killed more than 1,800 people. The disaster not only underlined the Netherlands' struggle with water, which has played an important role in the formation of the country's national identity, but also led to the creation of a national plan to protect the country against future floods. This so-called Delta Plan led to the construction of the Delta Works, a large network of protective infrastructures in the vulnerable lower parts of the Netherlands.

The Waterloopbos test site is a large water basin, 250 metres long and with the possibility of creating high waves, situated in the middle of a forest. Similar test sites were also used to develop waterworks for the port of Bangkok and the Danish coast, as well as for an oil port in Libya and the Willem Tunnel in Rotterdam. With the advent of computer simulation and other testing capabilities, these models gradually became obsolete. In 1996, the Waterloopbos laboratory was closed. A monumental artwork by RAAAF, which was completed in 2018, serves as a reminder of the area's former function, but also of the transience of the notion that the battle against water could only be won by developing indestructible structures[1]. Today, the Netherlands is at risk of even greater catastrophes as a result of sea-level rise, river water inflows and weather fluctuations causing severe droughts and heavy rainfall. Instead of "fighting the water", the new paradigm is "living with the water".

Figure 1.

Waterloopkundig Laboratorium De Voorst in the Noordoostpolder, Dam in the Haringvliet.
Source: Fotocollectie Rijksvoorlichtingsdienst

Waterloopbos is now a national nature reserve. The structures are overgrown and serve as a refuge for all kinds of life. But the importance of paradigm shifts and the different practices and forms of knowledge they enable is also evident in RAAAF's work. It illustrates how much imagination can be unleashed when there is broad discussion and an acute awareness of change. The construction of the Delta Works was preceded by intense debates among experts, politicians and citizens (Bijker 2002). This article will use these controversies and resulting compromises as an avenue for analysing how the Delta Works have engaged with time and temporality.

Infrastructures for adaptation to climate change relate to different regimes of time: geological epochs, the long-term consequences of fossil fuel use, investment cycles, technology development trajectories, the length of regulatory and legislative processes, the periods of executive power of elected governments, tipping points and points of no return, subjective perceptions of time, and even eschatological visions of the end of time (see Rothe 2020 on this last point). There is a dynamic interplay between these time horizons and deadlines on the one hand, and their respective cycles, rhythms and tempi on the other (Wallis 1970). The distinction between time periods and time landscapes (Adam 1998; 2006) is not sufficient, as these are interdependent and in constant motion and conflict. Time periods and time landscapes accelerate, amplify, slow down or even stop each other altogether, complicating notions of governance, agency, knowledge, and time in the Anthropocene (Chandler 2018). Relatively little attention, however, has been paid to the temporal dimension of climate change adaptation infrastructures and the ways in which infrastructures mediate between politics and time. The relationship between temporality and the infrastructures used to adapt to climate change remains to be explored.

To study this relationship, this article starts with a historical example and examines the further development and planning of the Dutch Delta Works in the era of human-induced climate change. Studying this infrastructure and the planning process that preceded it allows for an analysis of the various relationships between technologies and time, making it possible to distinguish various temporal regimes and to explore the transition between and transformation of these regimes. Adaptation policies increasingly emphasise the use of flexible instruments to make societies more resilient to climate change, especially when it comes to rising sea levels and turbulent river flows. While the Dutch have long framed their relationship with water as a battle, the term "water management" has gained popularity when referring to adaptation policy in the Netherlands, as a way or strategy of "living with water" (Wieringa and Arts 2006). Through a combination of dikes and protection mechanisms, including more flexible structures such as basins, Dutch policymakers aim to build a resilient infrastructure that can be adapted as predictions regarding the consequences of climate change evolve.

The experiments at the Waterloopbos test site and the Delta Works are good examples of how infrastructure can be understood as being composed of various kinds of "folds". According to Latour (2002), folds, movement, and time exemplify how technologies consist of heterogeneous layers of matter and space, but also of time. He illustrates this with an elegant example, which is worth quoting at length:

> The hammer that I find on my workbench is not contemporary to my action today: it keeps folded heterogenous temporalities, one of which has the antiquity of the planet, because of the mineral from which it has been moulded, while another has that of the age of the oak which provided the handle, while still another has the age of the 10 years since it came out of the German factory which produced it for the market. When I grab the handle, I insert my

> gesture in a "garland of time" as Michel Serres (1995) has put it, which allows me to insert myself in a variety of temporalities or time differentials, which account for (or rather imply) the relative solidity which is often associated with technical action. (Latour 2002, 249)

According to Latour, when "we would reverse the movement of the film of which this hammer is but the end product, we would deploy an increasing assemblage of ancient times and dispersed spaces" (*ibid.*, 249). Elaborating on this thesis, this article will explore the idea that infrastructures, like Latour's hammer, are not only made of matter, movement and space, but also of time. We will argue that infrastructures not only consist of heterogeneous temporalities, but that they can also be regarded as dynamically composed entities that mediate between different temporal regimes. As the development of infrastructures will be of paramount importance for the development and implementation of climate adaptation policies, it is crucial to arrive at a refined understanding of the relationship between infrastructures and time. Issues of policymaking, financial investment, public support, research and development all relate to different regimes of time. A heterogeneous conception of time and temporality is needed to do justice to the mediating role of infrastructures in all these issues.

To develop this perspective, this article is organised as follows. Section 2 analyses the relationship between temporality, infrastructures and climate change in order to situate the relationship between the Dutch Delta Works and time. The analysis elaborates on some key notions that have been proposed in the field of science and technology studies (Vostal et al. 2019) to explore the relationship between time and climate change adaptation infrastructures. In Section 3, these notions are put forward to empirically analyse the development of the Delta Works. More specifically, we focus on existing adaptation pathways maps that are being used to anticipate climate change. By examining four episodes, we demonstrate the multiple relationships between infrastructures and time, while also identifying several mediating moments in their development. Section 4 discusses the consequences of relating infrastructures to different temporal regimes and conceptualises the time-mediating aspects of infrastructures, and of the Delta Works in particular. Based on an analysis of various infrastructural projects, the notion of "infrastructural compromises" is applied to describe how infrastructures connect different regimes of time and mediate between them. Finally, in Section 5, we present our conclusions and suggest a number of topics for further discussion.

2. Hetero-temporality: The Interaction between Multiple Time Regimes

The idea to conceptualize the relationship between time, infrastructures, and climate change in terms of "mediation" is inspired by Bruno Latour's analysis in *Down to Earth* (2018). In this essay, he breaks with an eschatological notion of time. Latour argues that climate change and the new climate regime do not imply the end of the world or the end of time. We are not witnessing the apocalypse. Instead, we are forced to anticipate an ongoing process of time that will only intensify our relationship with the planet and other beings in a new climate regime. To use the terminology of the philosopher of history François Hartog, Latour refrains from considering the transition from the Holocene to the Anthropocene as a *Krisis* – the Day of

Reckoning, in the Christian tradition – but regards it as *Kairos*, a temporal rupture that indicates an intermediary between the time of human beings and the time of earthlings (Hartog 2021, 429; 2022, 220-224). *Kairos*, in this sense, marks a period of transition and mediation allowing for a more variegated perspective on the relationship between infrastructures and time.

The philosophy of history interpretation of the transition to the Anthropocene offers important insights with regard to conceptualising the relationship between time and infrastructures, while also allowing for alternatives to the notion of "crisis". But how to distinguish and differentiate between the various modes of time in the new climate regime and the different forms of mediation? As Marquardt and Delina (2021, 1) argue, "time has become a key reference point for measuring the success, failure, and progress of climate action", as evidenced by the centrality of 2030 and 2050 in climate policies. However, the concepts of time and temporality are rarely problematised. For that reason, they stimulate "a closer investigation of the politics behind time-making in energy and climate research" (*ibid.*, 4). While this call to pay more attention to the relationship between politics and time deserves support, looking for the politics *behind* time-making might not be the most promising way of doing so. The use of the word "behind" suggests an instrumental relationship between politics and time, in which the former is supposed to be an agent treating the latter as an object of its own will. We therefore propose differentiating between multiple modes of time and temporality.

Climate change infrastructures operate as specific clockworks that aim to adjust political decision-making on climate issues. Meanwhile, these "clocks" have their own time settings. In their analysis of the temporal complexity of scientific knowledge production, Vostal et al. (2019) aim to unpack the relationship between time and technological development. They carve out three categories that seem applicable to the functioning of climate infrastructures as well. The first category, *experimental* temporality, is the kind of testing of time that occurs in laboratory work, where natural processes are made malleable by speeding them up or slowing them down. To provide an example, we again turn to the aforementioned Waterloopbos. A tide usually lasts about six hours, but the configurations of the Waterloopbos test setup made it possible to simulate a tide in a matter of minutes (Bijker 2019). *Cognitive* temporality refers to the "intentionality and agility of agents" (Vostal et al. 2019, 795). According to the authors, this category of temporality can be conceived as two different modes: as *quick* aha moments (eureka!), or as a *slow* and incremental process of gaining insight into complex phenomena, such as climate change. Predictions based on modelling are an example of the latter mode, which we will illustrate by highlighting adaptation pathways. Finally, *institutional* temporality comprises the administrative, communicative and regulatory work involved in the development of technologies, varying from the time it takes to get a paper published to securing funding, and including every step of the process, from the initial planning stage to the pilot, project and scale-up phases (Vostal et al. 2019, 794-798). In the following, we bring institutional temporality into the realm of governance and government where repeating cycles (e.g., elections every four years, terms of office, the time between the initiation of a project or a law to its implementation) contribute to structuring those domains. A clear example of institutional temporality is the Delta Act, which stipulates various terms for review, tenure and expenditure. This three-fold structuring of the problem is useful for analysing climate change infrastructures and the Dutch "Nationaal Deltaprogramma" (National Delta Programme, NDP), as the next section will show.

3. The Hetero-temporalities of the Dutch Delta Works

To analyse the hetero-temporalities of the Dutch Delta Works, four interconnected episodes are presented here, each of which has to do with the relationship between the Delta infrastructures, time, and water management practices in the Netherlands. We refer to these four empirical accounts as "episodes" because this suggests a temporal sequence. Our analysis of the episodes draws on the three temporal categories of Vostal et al. (2019) set out above: experimental, cognitive and institutional. The episodes are interconnected through their continuity, bringing lessons from the past into the present, anticipating the future in the present. Moreover, the links between them are emphasised by folding various times and temporalities into contemporary water security practices. The four episodes are also interconnected because – as we aim to show – they all contain specific forms of mediating with time and different time regimes, and compromises between various forms of time. The first episode outlines how the response to the 1953 North Sea flood materialised in the practices of Dutch water managers. The second pertains to adaptive delta management and the delicate balance between on-time investments and in-time interventions. The third episode discusses the scientific development of a mechanism seeking to responsibly establish a balance between on-time investments and in-time interventions. The final episode focuses on the question of how adaptive delta management and adaptation pathways maps are being used in the context of rising sea levels in the Anthropocene. In these episodes, various times and time regimes, timescapes and temporalities are folded into each other, thereby bringing the past and the future into present political decision-making.

3.1 The Delta Works: From Infrastructural Innovation to Institutionalisation

After the 1953 flood, the Delta Commission was established. Its task was to make recommendations to prevent future deadly floods. The commission advised closing off some of the dynamic estuaries (i.e., Veerse Gat, Haringvliet and Brouwerhavense Gat) using caissons, discharge sluices and concrete blocks (Bijker 2002). While this infrastructure created a safe living environment for the local population, it had a devastating effect on natural life in the estuaries, as local ecosystems were altered irreversibly. The closure of Brouwerhavense Gat cut off the Grevelingen, effectively creating a dead body of water. In fact, two weeks after its closure, the Grevelingen was referred to as a graveyard. The newly created lake and its shores were covered with dead, rotting animals and sea plants. This ecological disaster significantly changed public discourse, leading to new water safety and management practices. As a result of this "radical departure from centuries-old traditions", the NDP and the Delta Act sought to ensure a balance between safety and ecology instead of focusing solely on the former (Bijker 2002, 570; 583).

The Grevelingen graveyard taught policymakers two key lessons about Dutch water management strategies. First, concrete barriers in estuaries are not conducive to natural life and ecosystem development. They literally cut off natural cycles, making it impossible for life to flourish. Second, constructing a concrete infrastructural dam means that the dam's hinterland is rendered static for decades or even centuries. Keeping bodies of water open instead of closing them off thus helps to sustain life while also keeping open the possibility of various future interventions. The NDP adheres to this ideal of "keeping open" through the notion of

Figure 2.
Construction of the Haringvlietsluizen, 1962.
Source: Fotocollectie Rijksvoorlichtingsdienst

adaptability. Taking anthropogenic climate change into account, the interdisciplinary field of water management and water safety in the Netherlands has invested in knowledge, planning and institutions to anticipate the many future uncertainties and requirements.

The continuity from the 1953 North Sea flood and the subsequent establishment of the first Delta Commission, also in 1953, is to be found in the second Delta Commission, which was established in 2007[2]. The remit of this second commission was to advise about water safety within the context of the projected sea level rise as a result of global warming. In its 2008 report *Samen werken met water* ("Working with Water Together"), the second Delta Commission conducted an integral analysis of the various water-related challenges faced by the Netherlands in the centuries ahead. The report is based on the premise that the Netherlands must continue to be:

> [An] attractive country in terms of living conditions, work, investing and recreation. Safety and sustainability are the twin pillars on which the strategy for the coming centuries must be based. The best long-term strategy to ensure that the Netherlands remains a safe and pleasant country to live in is *to align its development with climate change and other ecological processes*. (Delta Commission 2008, 89, *emphasis added*, *authors' translation*)

The second Delta Commission clearly acknowledged that future climate change and sea level rise would have a significant impact on the Dutch delta. It also noted, however, that the pace and effects of climate change remained uncertain. In this context, the commission proposed a sustainable strategy by formulating its recommendations in such a way that they could be “realised flexibly and gradually, responding to long-term developments” (Delta Commission 2008, 89, *authors' translation*). In other words, a number of key mechanisms to ensure the safety of the Dutch delta were formulated in 2008.

As a result of the second Delta Commission's recommendations, the NDP became legally established – and in that respect institutionalised. The NDP's position, including that of the Delta Commissioner, was laid down in the “Deltawet waterveiligheid en zoetwatervoorzieningen” (hereafter: Delta Act), in 2011. The Delta Act stipulates that there shall be a Delta Programme and a Delta Fund, with an annual budget of approximately €1 billion. It also sets out the powers and responsibilities of the independent government commissioner, whose term of office is seven years, with the possibility of renewal[3]. The purpose of the NDP is to ensure that the Netherlands remains safe, now and in the future, and that it has sufficient access to fresh water[4]. The NDP's ongoing tasks include signalling potential problems and adjusting policies and plans. It must report to the government and Parliament annually, and every six years the NDP's activities and objectives are recalibrated.

In this brief examination of the NDP, we observe mainly an *institutional* temporality, simply because the NDP is governed by a law that stipulates various time regimes (annual budget, recalibration every six years and a renewable seven-year term for the commissioner). This arrangement ensures the continuity of the NDP and the commissioner's work. At the same time, the commissioner's renewable seven-year term, together with their independent status and the annual prescribed budget, also keeps their work – and the NDP's work in general – relatively separate from the political domain and its short-term preferences and election cycles. This means that the institutional temporalities that partly constitute the NDP are coordinated in such a way that they are diachronic to the institutional political temporalities. But there's an order of temporalities, just as the political domain dictates that of the NDP.

3.2 Infrastructural Development as Investment

The “fight against water” and “keeping the polders dry” play a central role in Dutch policies and governance, and the Dutch have a long history of dealing with water and its turbulent tides, as well as a great deal of expertise in water management. However, it should also be noted that the development of the NDP involved several compromises. As historians have pointed out, compromises were an integral part of the decision-making process when water became a security issue (Kruizinga and Lewis 2018). One such compromise concerned the question of “how high is high enough” in terms of dikes and the investments needed to ensure water security. In the Netherlands, water levels are indicated as being above or below the Amsterdam Ordnance Datum (Normaal Amsterdams Peil, NAP). On Saturday, 31 January 1953, a high spring tide combined with a severe storm caused water levels to rise to over 4 metres above the NAP. However, the NAP delta norm of +5 metres, which was formulated to prevent future disasters and “would form the basis of Dutch water security policy for decades to come”, was based on financial and statistical “assumptions and compromises” that “remained largely unchallenged until the twenty-first century” (Kruizinga and Lewis 2018, 24). As Kruizinga and Lewis (*ibid.*, 24) have shown, it took until 2004 “to publicly recognize that the delta standard was unverifiable and remained untested”.

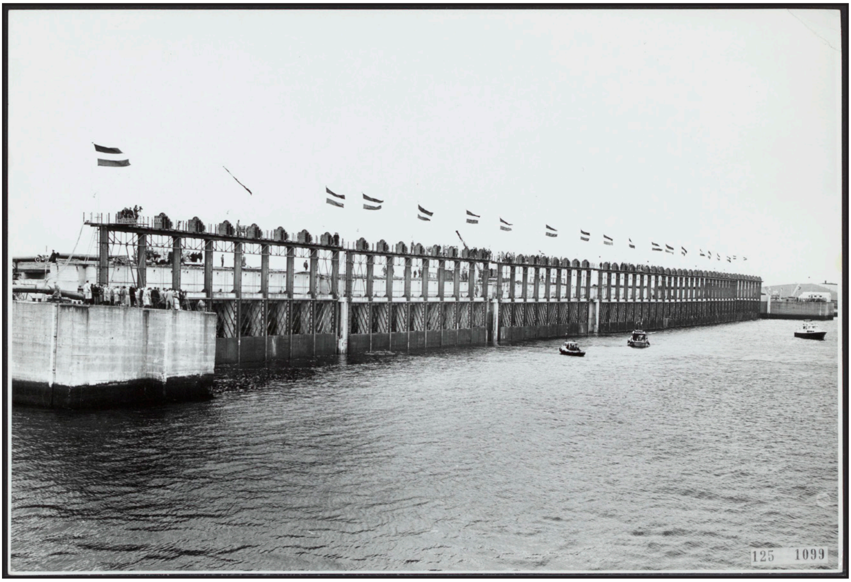

Figure 3.
Closure Veerse Gatdam, 1961.
Source: Fotocollectie Rijksvoorlichtingsdienst

The compromises made in the development of the NDP included financial and statistical aspects of water security, as well as different time regimes. In this respect, the lack of a scientific basis for the NAP delta norm in the 20^{th} and early 21^{st} century is highly problematic. Assumptions and compromises do not provide sufficient protection for the estimated 8 million people who live in areas that are prone to flooding. Because of climate change, growing existential threats will render traditional forms of water management through dikes, polders, pumps, dams or sluices partly obsolete. Whereas dangerously high tides were relatively easy to predict when sea water levels were stable, anthropogenic climate change is forcing Dutch water managers to take into account extreme long-term uncertainty. As a result, *adaptive* water management is becoming increasingly central to Dutch water security practices. Besides safety and sustainability, responsible adaptive water management also takes into account cost-effectiveness. On its website, the NDP defines adaptive delta management in various ways. For example:

> Working adaptively does not mean waiting until we are overtaken by new insights or developments, but being constantly alert and taking cost-effective measures at the right time[5].

Timing is at the heart of adaptive delta management. Infrastructural adjustments must be made *in time* to prevent floods, and investments must be made *on time* to ensure that they are cost-effective. This strongly resonates with the financial-economic rationale applied to trade-offs between contemporary financial investments and future benefits, or the discount rate. This rate converts "costs and benefits at different points in time into comparable costs and benefits at a single point in time", taking into account variables like interest rates and depreciation of commodities (Newell and Pizer 2001, 1). An effect of discounting is that a resource (e.g., €1) has a higher value in the present than in the future. This also means that benefits in the distant future are given less weight in the planning process than benefits in the near future (Broome 1994), and that investments with long-term benefits hence become more expensive than short-term investments (de Goede 2015). In other words, from a financial perspective, the best moment to invest in reinforcing a dike is as late as possible, because investing too early is not cost-effective.

This episode underlines how a financial rationale folds the long term into the short term, thereby valuing the latter higher than the former. Water security cannot be discussed without a cost-effectiveness analysis, which is de facto a political analysis because, as Wood (2008, 266-267) argues, the relationship between short-term decision-making and anticipating future events in terms of political benefits, introduces a "political discount rate" based on the present political value of the future benefits of a given action. In this respect, the episode about infrastructural development as an investment entails a hybrid between two temporalities: *institutional* and *cognitive*. The former is dependent of political cycles, such as elections being held every four years, but it also involves depreciation periods of 10 or 20 years, for instance. The cognitive temporality slowly evolves over time, as cost-benefit analyses are, similar to climate change, complex objects with regard to financing, where modelling, future projections, and interpretations and valuations of the past coincide.

3.3 Infrastructures as Temporal Interventions

In addition to on-time investments, in-time interventions are crucial in water management and safety. If a flood can be prevented, it should be. But climate change is a complicating factor in determining the right time for physical interventions. The scientific literature on climate change is clear on several developments. For instance, there is consensus on the fact that the pace of climate change is increasing, and that atmospheric and sea temperatures will rise accordingly (Loeb et al. 2021). It is also widely agreed that extreme climate change effects are difficult to predict as the increase in weather extremes potentially renders past observations obsolete when it comes to assessing current and future weather patterns (Thompson et al. 2023). But climate tipping points are difficult to predict. They come about abruptly and that they will have a significant impact (Lenton et al. 2019). These developments make it more difficult to predict, for example, the rate at which sea levels will rise. In this respect, Lenton et al. (2019) state that a tipping point may have been reached in West Antarctica, as the "grounding line" where "ice, ocean and bedrock meet is retreating irreversibly" (*ibid.*, 593). If this tipping point also destabilises West Antarctica's ice sheet, they predict a 3-metre sea level rise "during the coming centuries to millennia" (*ibid.*)[6].

Given that approximately a quarter of the Netherlands lies below the current sea level and almost 60% of the country is prone to flooding, the predictability of sea level rise is an important issue for the Netherlands. The NDP reports an expected sea level rise of 1 to 2 metres by 2100 if the 2015 Paris Agreement's targets are met[7]. If these goals are not met – i.e., if global temperatures rise by more than 2 degrees Celsius – sea levels will rise accordingly. Even in this brief example, there are various uncertainties: *a sea level rise of 1 to 2 metres by 2100 if global* *warming is limited to 2 degrees Celsius*. The NDP currently uses the Dynamic Adaptive Policy Pathways (DAPP) as a framework for decision-making in the face of uncertainty (Kwakkel et al. 2016; Haasnoot et al. 2018; Haasnoot and van 't Klooster 2018). Adaptive planning is about the identification of short-term actions and long-term options in relation to a specified plan, and requires active monitoring and signalling to ensure timely implementation or adjustment. The NDP's policy programmes and goals are consequently recalibrated every six years. DAPP defines various action series over time – so-called *pathways* – to achieve and secure future plans, based on the notion that policies, actions and decisions have an "uncertain design life and might fail to achieve their objectives sooner or later" (Haasnoot et al. 2018, 274). When DAPP determines that objectives within a particular programme will likely fail, it identifies these moments as adaptation tipping points. This indicates that targets will be missed and that a different policy pathway must be followed (see Figure 4).

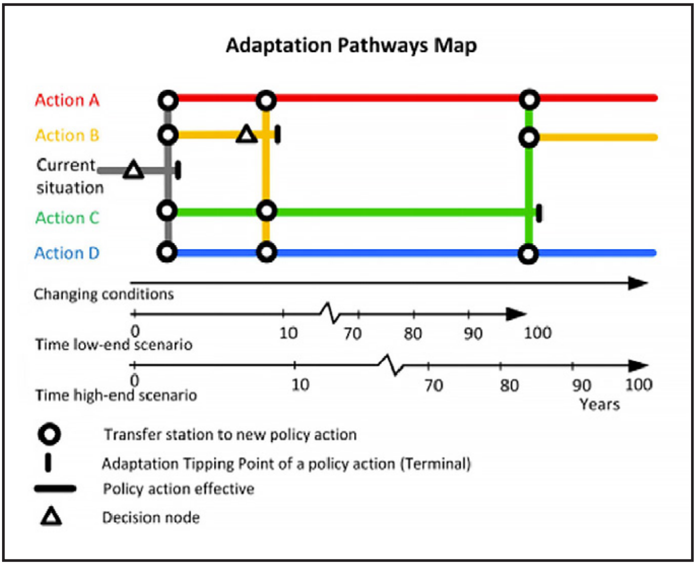

Figure 4.
Adaptive pathways map.
"An example of an adaptation pathways map [...]. In the map, starting from the current situation, targets begin to be missed after four years; an adaptation tipping point is reached. Following the grey lines of the current plan, one can see that there are four options. Actions A and D should be able to achieve the targets for the next 100 years in all scenarios. If Action B is chosen, a tipping point is reached within about five more years; a shift to one of the other three actions (A, C, or D) will then be needed to achieve the targets. If Action C is chosen after the first four years, a shift to Action A, B, or D will be needed after approximately 85 years in the worst case scenario (follow the solid green lines). In all other scenarios, the targets will be achieved for the next 100 years (the dashed green line)."
Source: https://www.deltares.nl/en/expertise/areas-of-expertise/sea-level-rise/dynamic-adaptive-policy-pathways

Thus far, we have looked at some of the complexities that the NDP must address. Among them are finding a balance between cost-effective investments and the right moment to build infrastructures to keep the Netherlands safe from flooding, and finding the best way to deal with uncertainties in relation to climate change developments and the effects of these global changes on sea levels. DAPP offers a method for navigating these challenges. In this respect, DAPP's temporality is about bringing the future into the present. DAPP's temporal map is hence an illustration of an *experimental* temporality, because it compresses the passing of time, from years to decades, into an orderly overview that dictates when what must be decided, as well as which potential pathways are left open and closed.

3.4 Infrastructures as Open Futures

What are the Netherlands' potential futures in relation to the struggle with water? It took the NDP, together with several scientific partners, years to fully develop adaptation pathways that can be implemented gradually, ensuring flexibility. With scenarios such as these – which provide the conditions for adaptability – the future is kept open to a certain extent. The adaptation pathways map provided above is schematic and rather abstract. Based on this method, Deltares developed four strategies for the Netherlands to cope with rising sea levels:

1. *Protect-closed*: protecting the coast from flooding and erosion through hard or soft measures, such as barriers, sand replenishment or wetlands. River arms are closed off (with dams or storm surge barriers);
2. *Protect-open*: same as above, but the rivers remain in open connection with the sea;
3. *Seaward*: creation of new, higher, seaward land to protect the delta from flood impacts;
4. *Adjust*: reduce vulnerability to the effects of higher sea levels through water- or salt-tolerant land use (e.g., buildings on stilts), raising land, spatial planning and/or migration. (see Haasnoot et al. 2019, *authors' translation*)

Each of these four scenarios has its own adaptation pathways. Similar to the adaptation pathways map above (Figure 4), the four scenarios also have adaptation tipping points, where a choice must be made to proceed on the chosen adaptation pathway or to stop and switch to another pathway. While some of the interventions are required in more than one adaptation pathway, other interventions render the other scenarios less likely. Consider Scenario 1: once river arms are closed off by concrete barriers, the only remaining option is to pump the river water into the sea. For example, if the Rijnmond and Oosterscheldekering were to be closed, the Seaward scenario would effectively become obsolete. Moreover, this would negatively impact the estuaries' ecosystems. However, scenarios for the distant future do still consider the possibility of diverting from Scenario 1 (Protect-closed) to other scenarios, such as Scenario 4 (Adjust). Over the past several years, adaptation pathways have matured. Hence, they now exhibit traits not only of *experimental* temporalities (see above), but also of *cognitive* temporalities. With regard to the latter, academics and practitioners worked closely together to develop a policy mechanism that provides insight into complex phenomena. This can be used, for instance, to decide which water security measures – or infrastructures – must be implemented at a given moment, and to determine the possible consequences a particular decision will have for future decisions. The relationships between the developed scenarios are illustrated in Figure 5, which also shows when and where adaptation tipping points can be expected.

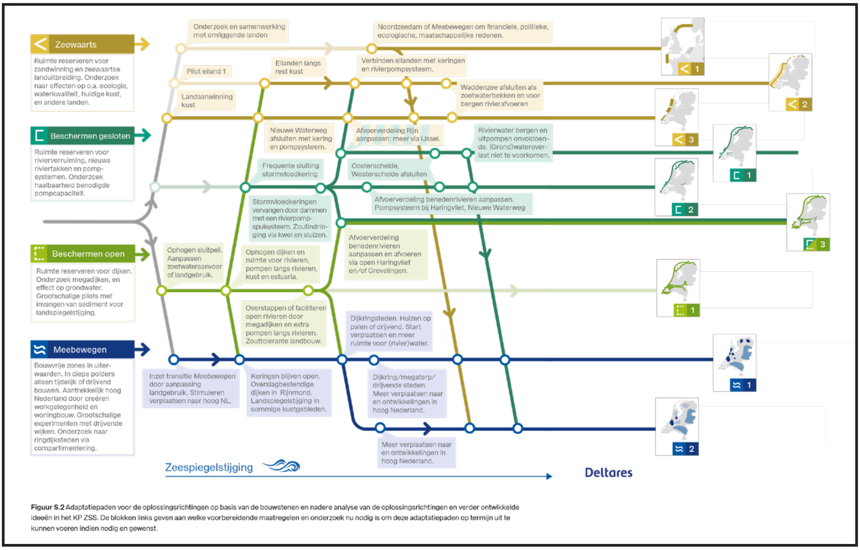

Figure 5.

Relationships between the four scenarios, including adaptation tipping points.
Source: Haasnoot and Diermanse 2022, 13.

The required preparatory measures and research for each of the four scenarios are described in the four blocks on the left. The dots indicate adaptation tipping points, clearly marking future moments that must be considered in the present. In addition, because some adaptation tipping points exclude particular scenarios, it is necessary to always bear in mind the desired future. DAPP is thus a mechanism that can be used to formulate visions and preferred situations for future generations living in the Netherlands. It maps all possible decisions and their respective sequences, both in the short and long term. In this respect, the pathways and adaptation tipping points are starting points for managing short-term actions and long-term options (Kwakkel et al. 2016; Haasnoot et al. 2018), offering ways to mediate between them and to arrive at possible compromises. While Figure 5 is itself an example of *cognitive* as well as *experimental* temporality, as we argued above, it also embodies *institutional* temporality. Although the scenarios and tipping points are not clearly articulated in Figure 5, the underlying document mainly refers to the years 2100 and 2150 (and a few times to 2200) which is an indication of the planning horizon. Moreover, there is a particular sequence of measures, as some interventions make others impossible. This present-day focus on the long-term and policy consequences, together with the specific sequences for implementing new infrastructures, show that adaptation pathways coincide with *institutional* temporalities.

4. Infrastructural Compromises: The Delta Works as Mediators of Time

Global warming and its consequences such as rising sea levels and flooding are becoming increasingly unpredictable. This requires new approaches when it comes to planning, building, and investing in the Delta Works infrastructures[8]. Adaptation pathways play an important role in this. The four episodes discussed above demonstrate how various temporal regimes underlie planning and policy to ensure a safe and liveable country, and how they produce infrastructures. This foundation on which the Delta Works are built is shaped by politics, which leads us to explore two questions in this section. First, can time-politics be linked to the literature on infrastructures? And second, are there concepts that can help us articulate how infrastructures mediate time?

4.1 Infrastructures and Time-Politics

The literature on infrastructures has identified four distinct features that are helpful in thinking about the time-politics of infrastructures (Dijstelbloem 2021; Rowland and Passoth 2015). First, infrastructures usually consist of large-scale networks that are linked to specific local situations. Not all infrastructures are large projects that are designed and implemented top-down; they also emerge from singular events that form the building blocks of later structures. The notion of infrastructure does not reduce a myriad of technological policies and practices to a single constellation. Infrastructures shape shared worlds, not necessarily by directly providing public goods or shared facilities, but by producing particular connections that shape all kinds of associations between people and technologies. If infrastructures relate the general to the particular, a similar argument can be made for the infrastructural production of time and timing. The first two episodes from the previous section support this claim. Institutional temporalities as described in the first episode – annual budgets, recalibration every six years and a renewable seven-year term for the commissioner – also bring about the infrastructures themselves in a particular order, at particular moments in time, and timed to strike the right balance between necessity and cost-effectiveness. The latter is the outcome of a cognitive, slowly evolving temporality focusing on future projections and interpretations and valuations of the past.

Second, while infrastructures aim to create shared worlds, they can privilege some groups over others. Infrastructures include and exclude, they select and prioritise[9]. The second point can be elaborated by recognising that the benefits of time are not equally distributed. In other words, the people affected by short-term policies are not necessarily the same as those affected by long-term policies. Climate change is a good example. While past and present generations in the Global North are responsible for emitting large amounts of greenhouse gases by taking economic advantage of industrial infrastructures, future generations and people living in the Global South will bear a disproportionate share of the consequences of this behavior and lifestyle. Meanwhile, the Netherlands can afford to build protective infrastructures to ensure the long-term safety of people living in the Dutch Delta, thinking ahead to 2100 and 2150, while similar infrastructures are lacking in many vulnerable Delta areas in the Global South. At the national level, issues of distributive justice are also likely to be addressed through climate adaptation infrastructure. Countries are already implementing policies and strategies of "anaged retreat" and "coastal retreat", continuing to protect some areas while reducing support for others (Siders et al. 2019).

Third, infrastructures are particularly concerned with the interplay between the visible and the invisible. As Larkin (2013, 336) argues,

> [I]nvisibility is certainly one aspect of infrastructure, but it is only one and at the extreme edge of a range of visibilities that range from the unseen to the grand spectacle and everything in between.

Infrastructures are composite entities that visualise and reveal specific events at different moments in time and space. This point emphasises that the relationship between infrastructures and time is not always visible. Again, this is illustrated by adaptation pathways, as these anticipate anthropogenic uncertainty and unpredictability. Consequently, plots of land or whole areas must be reserved to allow for the construction or expansion of future infrastructures. In this respect, future infrastructures are invisible (they do not exist yet) but nevertheless discernible as areas yet to be developed. Here we see how the Anthropocene's long-term uncertainty and unpredictability produce land, for instance in anticipation of rising sea levels.

Fourth, infrastructures are not just robust and stable building blocks that form the technical backbone of society. They are often highly mobile, intervening in specific situations. This point can be understood to mean that the development of infrastructures is not a linear process, but one that is characterised by accelerations, delays, tipping points and points of no return, as illustrated by DAPP.

4.2 Infrastructures Mediating Time

The four characteristics mentioned above contain various tensions, such as between the general and the particular, visibility and invisibility, and inclusion and exclusion, that are constitutive for infrastructures. Bowker and Star (1999) introduced the term "boundary infrastructures" to describe these constellations that mark, maintain and also emerge out of the juxtaposition of coherence and fracture[10]. For the purposes of this article, one of the interesting aspects of boundary infrastructures is precisely their mediating role. Below, we will explore whether infrastructures also mediate time. Do infrastructures perform as mediators that connect different temporal regimes? And are they capable of generating temporal regimes? If we continue the analysis of boundary infrastructures and look beyond their material and spatial characteristics to their temporal aspects, we might be able to formulate tentative answers to these questions.

One possible way to explore the mediating role of infrastructures is to examine the notion of compromise. Elaborating on the work of Boltanski and Thévenot (2006), Dijstelbloem (2021) applies the concept of compromise to the study of infrastructures. Compromises, in this context, are combinations of different technological systems that express opposing values.

> Wildlife crossings such as underpass tunnels, viaducts, fish ladders, and amphibian tunnels can be seen as infrastructural compromises between economic considerations of mobility and ecological considerations of keeping habitats connected. (Dijstelbloem 2021, 95-96)[11]

Applying this conceptualisation to the Dutch Delta Works makes it possible to identify a number of specific compromises.

One of these compromises appeared in the first episode, namely the attempt to avoid new ecological disasters after the closure of Brouwerhavense Gat, which cut off the Grevelingen. In order to create a new ecological connection, the Oosterscheldekering was developed (Bijker 2002). This 9-kilometre-long storm surge barrier was originally designed, and partly built, as a closed dam, but after public protests, huge gates were installed in the remaining 4-kilometre stretch to maintain the rhythm of the tides. Dijstelbloem (2021, 96) describes these as "sluice-gate- type doors, which allow saltwater marine life and local fishing behind the dam but can be closed when weather conditions require it". In other words, the gates are a compromise between security concerns and ecological requirements, allowing life to flourish and protecting the area's biodiversity. Twice per day, 800,000 billion litres of saltwater flow in and out of the Oosterschelde, helping to sustain a rich biodiversity by providing a home for non-migratory animals, a nursery for many species and a "roadside restaurant" for migratory birds[12].

Another compromise in the second episode concerned the discount rate, the financial-economic rationale for trade-offs between contemporary financial investments and future benefits that is used to strike a balance between cost-effectiveness and security when it comes to investing in flood prevention. A third example of a temporal infrastructural compromise were the climate change adaptation pathways that are being developed and implemented, as described in the third and fourth episodes. The NDP uses an adaptive strategy in this context to structure its present and future actions. Adaptive water management is discussed in many publications, but the following example corresponds to the episodes discussed above:

> In an adaptive plan, adaptation pathways capture the implementation process by specifying which measure(s) are to be taken now and which are planned to be implemented once certain conditions occur [...]. As such, adaptation pathways explicitly consider uncertainty and embed flexibility within planning. (Werners et al. 2021; see also Kwakkel et al. 2016).

Finally, the fourth compromise that can be identified concerns the management of short-term actions and long-term options by adjusting tipping points to align with starting points for climate adaptation action, or the management of the various temporalties described in the four episodes.

5. Conclusion

The Delta Works are a landmark in modern Dutch history and an international symbol of water management. Although their genesis has often been highlighted, the relationship between these infrastructural projects and time, and especially the heterogeneity of time, has received little attention. More generally, the analysis presented here aims to advance the conceptualisation of the relationship between time and different infrastructures. By shifting the perspective from *Krisis* to *Kairos* – from a response to immediate catastrophes to a period of transition and transformation – the Delta Works can be viewed as infrastructures that embody different relationships with different regimes of time. Moreover, the analyses presented above suggest that infrastructures can also be seen as mediators of time, as the result of compromises between different temporal regimes. Given that the development of infrastructures will be of paramount importance for the development and implementation of climate adaptation policies, it is crucial to arrive at a refined understanding of the relationship between infrastructures and time. Challenges related to policymaking, financial investments, public support, research and development all relate to different regimes of time. A heterogeneous conception of time and temporality is needed to do justice to the mediating role of infrastructures in all these issues.

The first conclusion that can be drawn is that the notion of mediation as developed in the fields of science and technology studies (Latour 1994) and philosophy of technology (Verbeek 2016), which resonates with concepts such as "boundary infrastructures" and "infrastructural compromises", does not have to be restricted to mediation between humans and nonhumans, but can also be used to describe mediation with time and temporal regimes. Second, as demonstrated by the reference to the distinction by Vostal et al. (2019) between experimental temporality, cognitive or intentional temporality, and institutional temporality, the study of infrastructures and time should also include an analysis of how various forms of knowledge and scientific research relate to different forms of time. Third, elaborating on the notion of infrastructural compromises allows for the identification of specific forms of mediation between infrastructures and time. The episodes about the history of the Delta Works demonstrated the relationship between infrastructural experiments, innovation and institutionalisation on the one hand, and different time regimes and the interaction between time and timing on the other. This included a discussion of how the future is related to present to make investment decisions, as well as an examination of how pathways are conceived as a way of working with open futures, anticipating unforeseen ruptures in temporal regimes. Fourth, infrastructures can be seen as mediators themselves – mediators that create regimes of time. Infrastructures tend to function as vehicles that mediate between different regimes, rather than as artefacts that accelerate time's arrow and that are required to reach future adaptation goals as quickly as possible. They may connect and disconnect the present and the future *in different ways*, thereby enabling possible tipping points and preventing lock-ins and path dependencies.

The above analysis of the development of the Dutch Delta Works speaks to the progress made through various climate adaptation infrastructures. It shows that the interaction between past, present and future does not take place on a linear time scale, but is characterised instead by a hetero-temporality consisting of different, often conflicting time regimes (see for example the institutional temporalities of the NDP, which focus on the long term and were designed so as to not coincide with the political cycles or be affected by the short-term focus of policymakers). The time paths of political decision-making, technological development and financial investment vary and have a complicated relationship with the speed and, above all, the tipping points of climate change. At first glance, the debate about the need for new technologies to adapt to climate change fits into a "race against the clock" framework, in which technologies are seen as instrumental to achieving certain goals and levels of protection and security at a certain point in time. From this perspective, it is not surprising that the development of technologies is discussed in terms of trajectories. However, given the winding roads that characterise infrastructure development, a perspective that allows for more hetero-temporality would be better aligned with the paths that technological trajectories are likely to take. The development of climate change adaptation infrastructures is deeply permeated with variable time regimes and hetero-temporalities. Taking path dependencies, possible lock-ins, points of no return, feedback effects and tipping points into account is crucial, and so is the mediating role of infrastructures in navigating the different time regimes that affect climate adaptation policies.

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Notes

[1] See: https://www.architectuur.nl/project/deltawerk-van-raaaf-en-atelier-de-lyon/ (retrieved October 28, 2023).

[2] The first Delta Commission was established after the 1953 North Sea flood.

[3] Dutch Water Act, Article 3.6, see: https://wetten.overheid.nl/BWBR0025458/2023-07-01#Hoofdstuk7_Paragraaf4a_Artikel7.22a.

[4] https://english.deltaprogramma.nl/; see also Memorie van Toelichting, 32304, nr. 3: https://www.parlementairemonitor.nl/9353000/1/j9vvij5epmj1ey0/vick7ow0jvzz.

[5] https://www.deltaprogramma.nl/deltaprogramma/wat-is-het-deltaprogramma/adaptief-deltamanagement (*authors' translation*).

[6] The reported 3-metre sea level rise is related to the melting of the ice sheet in West Antarctica. If global temperature rise is considered, estimations range from a 0.5- to 2-metre sea level rise by 2100. In scenarios based on a temperature rise of 3 degrees Celsius, the IPCC considers a 5-metre sea level rise possible, see: https://www.ipcc.ch/srocc/chapter/chapter-4-sea-level-rise-and-implications-for-low-lying-islands-coasts-and-communities/.

[7] https://www.deltaprogramma.nl/deltaprogramma/vraag-en-antwoord/hoe-zit-het-met-de-zeespiegelstijging.

[8] Like the Delta Works, transportation networks, roads, railways, power grids, communication networks, digital infrastructures and knowledge infrastructures have been central to the study of infrastructures, and have entered the Anthropocene (Anastasiadou 2011; Barry 2013; Edwards 2003; Guldi 2012; Janác 2012; Lagendijk 2008; Lommers 2012; Mazur 2013; Misa et al. 2003; Pritchard 2011; Schueler 2008).

[9] The typical example to refer to is Langdon Winner's (1980) account of the Moses bridges, a network of infrastructures in Long Island, New York. These bridges were designed, according to Winner, to prevent buses from getting through, thereby limiting access to the beach and park for racial minorities, who typically travelled by bus. However, Winner's account has been heavily criticised and partly debunked (Joerges 1999; Woolgar and Cooper 1999).

[10] Merriman and Jones (2016) have argued that boundary infrastructures play "a central role in mediating the nation's heterogeneous internal relations" (Brady 2021). They state that "not only do the material and elemental properties of mobility infrastructures afford or enable particular practices,

but they also get caught up in affective relations or atmospheres" (2017, 7). The example they provide is that of Severn Bridge, "which unites Wales and England even as it demarcates between them: a literal boundary infrastructure, it means different things from different culturally and materially situated perspectives" (Brady 2021).

[11] Another example concerns so-called humanitarian borders, which combine humanitarian and security considerations, often resulting in compromised compromises.

[12] See https://www.np-oosterschelde.nl/discover-the-story-of-the-easter-scheldt/ (retrieved October 26, 2023).

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