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On behalf of:

Federal Ministry
for the Environment, Nature Conservation,
Building and Nuclear Safety

of the Federal Republic of Germany

The Role of Climate Data in the Planning Processes in Germany for Bridges, Hydropower Dams and Coastal Protection/Dyke Construction

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Image 1 – *Bridge construction site*

Image 2 - *Coastal protection, dkye*

Image 3 – *Hydropower dam*

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Abbreviations

BASt	Federal Highway Research Institute/ Bundesanstalt für Straßenwesen
BAW	Federal Institute for Hydraulic Engineering/ Bundesanstalt für Wasserbau
Bfg	Federal Institute of Hydrology/ Bundesanstalt für Gewässerkunde
BMVI	Federal Ministry of Transport and Digital Infrastructure/ Bundesministerium für Verkehr und digitale Infrastruktur
BGF	Federal Institute for Geosciences and Natural Resources/ Bundesanstalt für Geowissenschaften und Rohstoffe
BSH	Federal Maritime and Hydrographic Agency/ Bundesamt für Seeschifffahrt und Hydrographie
CDC	Climate Data Center
CSI	Enhancing Climate Services for Infrastructure Investments Project
DAS	German Adaptation Plan/ Deutsche Anpassungsstrategie
DIN	German Institute for Norms/ Deutsches Institute für Normung
DWD	German Meteorological Service/ Deutscher Wetterdienst
ESFG	Earth System Grid Formation
GFCS	Global Framework for Climate Services
GIZ	Gesellschaft für Internationale Zusammenarbeit
GLOWA Danube	Global change in the Water Cycle/ Globaler Wandel des Wasserkreislaufs
ICZM	Intergrated Coastal Zone Management / Integriertes Küstenzonen Management
KLIMZUG	Design Climate Change in Regions in a Sustainbale Way/ Klimawandel in Regionen Zukunftsfähig Gestalten
KLIWA	Climate Change and Water Management/ Klimaveränderung und Wasserwirtschaft

KLIWAS	Climate Change on Waterways/ Klimawandel auf Wasserstraßen
RE	Guidelines for planning process & draft design documents in road construction/ Richtlinien für die Entwurfsgestaltung im Straßenbau
UBA	Federal Environment Agency/ Umweltbundesamt
WASKlim	Klimawandel und Wasserwirtschaft
WSV	Federal Waterways and Shipping Administration/ Wasserstraßen- und Schiffsfahrtsverwaltung des Bundes

1. Introduction

The incorporation of climate change into infrastructure planning is one of the greatest challenges of the 21st century. For many years infrastructure has been planned without incorporating long term planning strategies adapting to climate change. Although planners have considered it, not enough alternatives where incorporated, as they assumed the climate will stay constant. As a result, not only individuals are threatened, but the economy as a whole. Many infrastructure projects in Germany are already facing the threats of climate change (Adaptation Action Plan of the German Strategy for Adaptation to Climate Change, 2011). The most evident example can be seen in coastal protection and flooding adaptation measures. Due to insufficient planning and usage of climate services and predictions, adaptation measures failed under the threat of climatic events. Such an example can be seen in the floods in Dresden, Hamburg and other cities in many conceding years, where the waters still managed to flood the city, although adaptation measures had been put in place (Floodlist, 2018). In addition to this, many bridges, hydropower dams and other infrastructures have seen failures due to underestimated planned measures of the time. As one can see, climate change therefore leads to a greater vulnerability of such infrastructures and imposes a threat to the future generations and livelihoods of individuals. Therefore the question arises of, how the planning of certain infrastructure projects work and where the entry points for climate data under current methods are? When this is assessed, the current planning processes have to adapt these entry points to incorporate climate services and projections in a sense of making the infrastructure more resilient towards climate change.

The act of planning, organizing and constructing any infrastructure project however is a very complex and comprehensive topic. The process runs through a lot of steps and incorporates a vast sum of actors involved. Well planned and long lasting infrastructure is the backbone of a healthy economy. ”Infrastructure enables trade, power businesses, connects workers to their jobs, creates opportunities for struggling communities and protects the nation from an increasingly unpredictable natural environment” (Puentes, 2015). In Germany the political system is polycentric and decentralized, meaning it is the job of the federal states to set priorities and make political decisions, based on the scientific information and financial support provided by the national government (Lorenz et al, 2017). Therefore new projects have to be communicated clearly and agreed with the government, states and individuals before implementation. There are many steps in this process and therefore these have to be monitored and organized accordingly. Setting this into the climatic agenda, the question arises, where and when climate data plays a role and how strong it influences the planning processes. As infrastructure projects aim to have a long life span, the incorporation of climate change needs to be evident, as these projects will be exposed to the effects of climate change.

For years scientist and meteorologists have been collecting and analyzing weather patterns and trends and generating climate data, however up until recent years, climate data has never been seen to have a big influence in the planning process for future events. Nonetheless, with our changing environment steering to more extreme events, the idea of incorporating climate data into long term planning has gained greater importance. In order to sustain the standard of living of individuals in Germany under the threat of climate change, the federal government has established a German Adaptation Plan (Deutsche Anpassungsstrategie (DAS), 2008). This sets the fundamentals of a medium-term process, to identify risks and adaptation measures for individual federal states. Through this, regional and national projects or areas of work were appointed to implement this strategy. The Expert network for example, was founded by expert authorities of the Federal Ministry of Transport, Building and Urban Development (BMVI) in order to address urgent traffic issues of the future through innovations in the areas of climate change, environmental protection and risk management (BMVI, 2016). A further initiative called KLIMZUG contributes to the issues of adapting to climate change (Klimzug.de, n.p). The Umweltbundesamt (UBA) mostly initiates and takes part in projects and is mainly responsible for vulnerability analysis (Sander, 2018). Lastly there are also many university projects working towards the implementation of adaptation strategies.

1.1 Motivation

In a broader context, this report intends to assist the GIZ and DWD in their project "Enhancing Climate Services for Infrastructure Investments" (CSI). The CSI project wants to enable the usage of climate services in the planning and management of climate resilient infrastructure for public authorities and decision makers in Vietnam, Brazil, Costa Rica and the Nile Basin Initiative. This report therefore should provide examples of the planning process and entry points for climate data of Germany in three different infrastructure types, similar to the partner countries and aid as a way of understanding of how the process works in Germany.

1.2 Aim of the Report

In a narrower context, this report aims to give an overview of the planning processes in Germany for bridges, hydropower dams and coastal protection. Furthermore an in depth analysis of when and how climate data influences this process, will take place. Diagrams and examples will aid this process in defining key entry points for climate data. Certain codes, standards, norms and regulations will be assessed to understand how the decision making processes are influenced. Finally, setting this to the current agenda of climate change, this report will illustrate the way in which climate data is used to adapt these processes to climate change. By providing examples this report will assess in which steps of the process climate information is involved, how binding the use and reconciliation climate information is and if this process is formal or institutionalized.

1.3 How to access climate data in Germany

According to the GFCS Implementation Plan, climate data can be defined as the "historical and real-time climate observations along with direct model outputs covering historical and future periods" (WMO, 2014). Climate data can come in all various forms. Examples of such climate data or forms can be climate data sets, climate basic statistics, climate monitoring/diagnostics, monthly, seasonal or decadal climate projections, climate change projections, or climate scenarios: climate extreme events (hazards) either as historic, monitoring and forecasts. These generate different products which in return can be used for planning processes (WMO, 2012). These products are therefore described as a "synthesis of climate data". As result climate information, described as "climate data, climate products and/or climate knowledge", gets transferred (WMO, 2014 pg.2). These products that then are further combined with other relevant information in order to provide data and information for adaptation, mitigation and disaster risk are called climate services (European Union, 2015). So in other words, climate services aim to aid the decision making process for individuals and organizations (WMO, 2014, pg.2)

The question here however is where different individuals, organizations or authorities retrieve such climate data. Climate data can come from all different kinds of sources. For atmospheric data the German Meteorological Services (DWD) is the prime access point. The DWD "releases and publishes weather information and warning bulletins to customers and the general public on regular basis and depending on the weather situation". It provides monthly and daily data for precipitation, wind speed, temperature, sunshine duration, cloud cover, air pressure and humidity. These are updated daily and hourly (Deutscher Wetterdienst, 2017).

There are a number of ways to access climate data in Germany through the DWD. Firstly through the website of the DWD a link can be accessed which displays a Climate Data Center (CDC) FTP Server [1] . On this server there is a lot of raw data and climate information from Germany openly available for each individual. A second method of how to retrieve climate data is through e-mail or calling the customer service. Either through other projects the coordination and contact is already persisting or gets newly enforced through the call. The customer service then tries to find out what the customers' needs and wishes are and if these are feasible. Here different data portals such as Earth System Grid Formation (ESFG-Notes) are used to extract the specific data for the customer. Once the job is done, the data is placed on a FTP Server for the customer to download. After that the DWD still offers technical assistance where there is help needed in interpreting the data. Furthermore a lot of information can be accessed through various different institutions, agencies or universities. At last, the DWD and the UBA are working on opening a climate portal "Deutsches Klimavorsorge Portal" which contains climate services from various federal agencies. This website enables every user to get access to climate information and certain links for different areas, regions and variables in an easy and fast way.

Other key climate data such as ocean data gets accessed from the Federal Maritime and Hydrographic Agency (BSH) (BSH, 2018). Data from river and lakes is published by the Federal Institute of Hydrology (BfG) (BfG, 2017). To receive data about the groundwater, the Federal Institute for Geosciences and Natural Resources (BGR) is the key first point of contact (BGR, 2018). Data for water levels get produced by the Federal Waterways and Shipping Administration (WSV) (WSV, 2017) and in addition the Julius-Kühn-Institute provides data about phenology and harvest (JKI - Bundesforschungsinstituts für Kulturpflanzen, 2018). At last, the Federal Institute for Hydraulic Engineering (BAW) provides data for the waterways and shipping administration (BAW, 2018). This shows the big range of climate data available in Germany.

2. General Procedure for:

2.1 Bridges

Over 70% of all goods are being transported on roads with increasing measures. The German road network incorporates more than 53,000km of roads and more than 38,000 bridges and tunnels (Torrenti & La Torre, 2016). Large trucks carrying heavy loads produce more than 10.000 times the

[1] ftp://ftp-cdc.dwd.de/pub/CDC/

damage than that of cars (Dösser, 2011). The main issue here is that bridges deteriorate faster than their rehabilitation process takes, leading to a massive delay in new provision and bridges often being in a bad standard. Furthermore climatic events also influence the lifespan of a bridge. As bridges are so exposed, they are very vulnerable to climatic changes. Periods of long term extreme heat have an effect on the bridge materials as they can lead to these drying out and cracking. As well as that, bitumen, a material used for building, can melt or crack during a period of high and continuous temperatures, due to heat expansion and moisture loss. Overall however timber and clay materials are more susceptible to damage. In addition precipitation also imposes great challenges. Precipitation can come in two forms, snow and rain. Snow leads to heavier loads on the bridge and rain leads to erosion of sediments and structures of the bridge. At last, strong winds can harm the railing and put more force on the bridge on one side. A bridge over a sea has an increased volatility due to the warming up of the waters influenced by to the rising air temperatures leading to global sea level rise. In addition there can be higher evaporation rates especially over a lake or river, leading to more moisture and humidity and ultimately to more corrosion (Blakely, 2007). One can now see how vulnerable bridges are to climatic conditions and changes. Hence planning and maintenance have to work effectively in order for the bridge to sustain these elements for the expected lifespan of 80 to 100 years (Torrenti & La Torre, 2016).

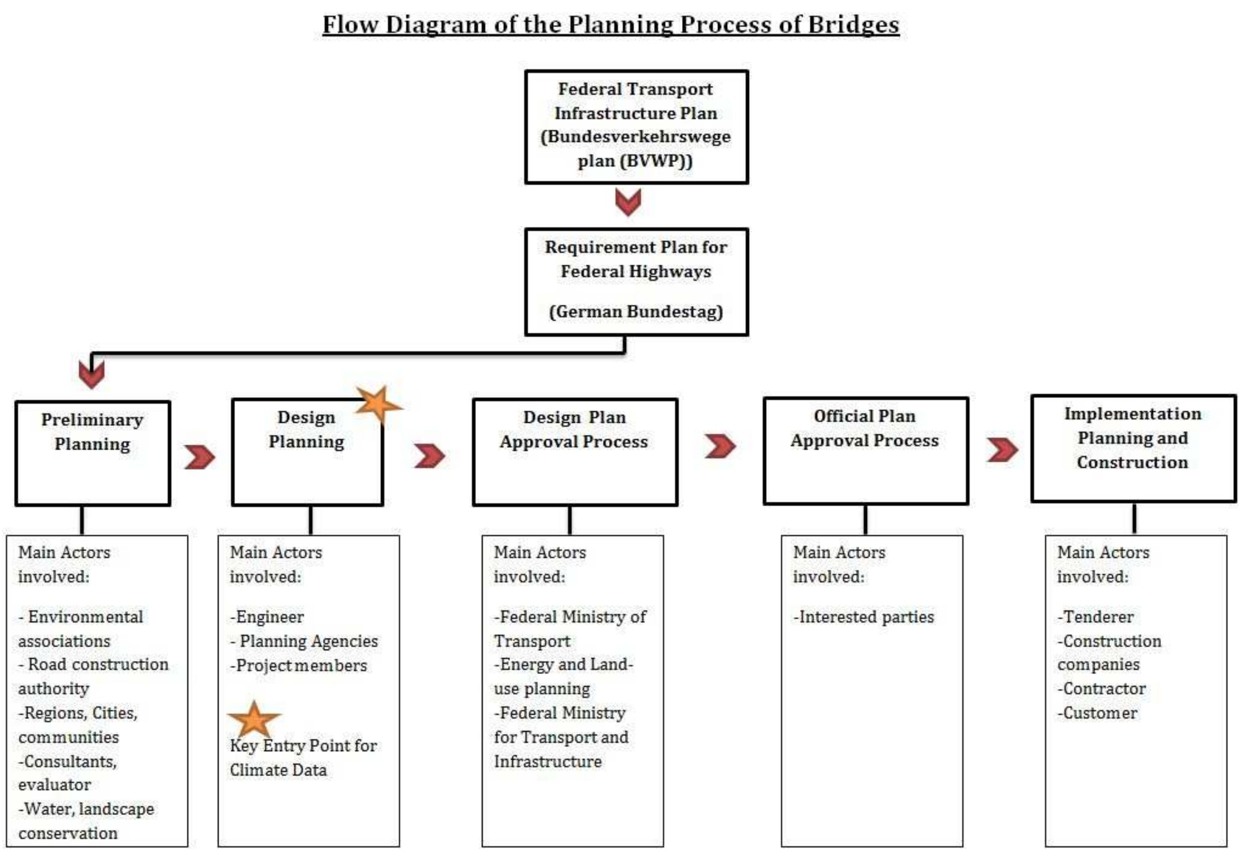

Figure 1: Flow Diagram of Planning Process of Bridges (mostly federal highways) (Strassen.NRW)

The general planning processes for bridges or engineering works in Germany follows through a lot of procedures and tasks before the implementation phase, as seen in Figure 1. Although this process is generally associated to each individual federal state, the course of action is more or less identical and follows a five step procedure (Haardt, 2018). Firstly a requirement plan (Bedarfsplan) has to be established by the government and state, which is the legal basis for new construction and expansion of roads and bridges in Germany. Since the mid-1970s, the government has developed the Federal Transport Infrastructure Plan (Bundesverkehrswegeplan) which decides on the urgency of projects, takes the availability of resources into account and sets priorities for public investment decisions for all road, railway and waterway projects. It acts as the basis of the requirement plan. The requirement plan determines the need for the extension of highways, the new construction of a highway and the new construction and extension of highways including the construction of bypasses. As soon as the construction laws and the bridge or road construction plan are completed, the project can be implemented. Secondly a determination of what line or where the bridge exactly should be placed is necessary. To do this, possible alignments of a road or bridge are examined. During this the current situation and location of different factors has to be analyzed. For example, a map is used and different areas of towns, working spaces, protected areas, habitats for animals or certain plants, etc. are marked. This enables the planners to visualize certain locations which could be possible for building a road or a bridge. During this multiple options are evaluated and conceptualized. The decided upon route is then further used in the preliminary planning to assess the environmental impact study and effect this will have on the traffic, finance and the economy. This is then openly displayed for the general public, citizens and other authorities to give an opinion about the planned project. After this is set, the planning of the design (Entwurfsplanung) is initiated. Here specific regulations have to be met such as ensuring the route is the environmentally friendly option, all security requirements are met, the required performance is guaranteed and that the necessary efficiency is taken into account. Overall it is impossible to meet all requirements and regulations; however they all have to be considered. Specific codes and standards for the conceptual design in the construction of roads (RE) are used to create the first documents. These include, the explanatory report to the draft, plans, maps, cross-sections, technical noise investigations, the landscape plan, cost estimates, technical water designs, quality analysis of the soil and air, etc. These documents then become reviewed and approved by the individual state ministry of road construction and the Federal Ministry for Transport and Digital Infrastructure (BMVI). Conceding this, the next step describes the plan approval process. The point of this process is that all legal issues about the construction project are examined and are weighed against each other as well as the public and private interests, without further public procedures or other governmental approvals. This process incorporates several steps which involve the establishment of plan approval documents, the hearing proceeding, the public display of the plan, citizen information and participation of the affected, objections and suggestions, date of hearing approval process and the administrative finality of the plan where the road administration authority receives the approval decision for the building project. To finalize the entire process the last procedure incorporates the detailed design and construction. Here the preparation of the execution documents on the basis of the RE preliminary decision and incorporate data on terrain sections and signposting, marking and protection plans. In addition these plans are then tendered and incoming offers are examined, analyzed and assigned, leading to a start in the construction process (Strassen.nrw.de, n.d).

Knowing how the planning process of a bridge or engineering construct is undertaken, the next question lies within the fact of where climate data takes its importance. In general terms the planning process starts in the commune who gives information in advance and then gets transmitted to the engineering offices. Here a more in depth planning and analysis of how to build the bridge is carried out. Climate data has always been used in the planning processes for a bridge however it is gaining more and more importance. Climate data mostly flows in the phase where the engineers plan the construction of the bridge, symbolized by the star in Figure 1, however also take importance when carrying out the environmental impact study. Most materials and how a bridge should be built is described in codes and standards. These also describe with what different values and figures the construction phase should be accounted for. The DIN Norms 1991 1-5 describe the way bridges have to be built. These are updated every 5 years, and aligned with the new findings and research. These DIN Norms describe so-called load models (Lastmodelle) which describe the factors which have an effect on the bridge. The climate data that is used here is temperature, wind and precipitation also in form of snow (Konstruktionsgruppe Bauen AG Kempten, 2018). Engineers have researched how bridges can withstand different climatic vulnerabilities. These include heat/frost-related damages and restriction to bridges, damages caused by freeze-thaw-cycles, high water or storm, the weight of snow, differing wind strengths (Korn et al., 2017). The biggest influence and factor leading to a failure in a bridge, is knowing what the expected weight of traffic on the bridge is. Knowing this the other factors start gaining their importance (Konstruktionsgruppe Bauen AG Kempten, 2018).

Overall however climate data has always, and will continue to, play a role in the planning especially in the design planning of a bridge. Builders combine the two different materials concrete and steel into one construction, which almost have the same expansion factor under the influence of temperature (Wetzel, 2018). Under normal conditions an engineer planning a bridge uses the set of air temperatures for their bridge. These include a minimum of -24°C and a maximum of +55°C. As these temperatures almost never get reached in Germany, it is safe to say that the bridge is in a good condition to endure temperature fluctuations within this range. This also shows that during the planning of a bridge values are used which would not really occur and are quite abstract, however this ensures the safety of the bridge (Konstruktionsgruppe Bauen AG Kempten, 2018).

Windzone	$v_{b,0}$ in m/s	$q_{b,0}$ in kN/m^2
1	22,5	0,32
2	25,0	0,39
3	27,5	0,47
4	30,0	0,56

Mittelwerte in 10 m Höhe im ebenen, offenen Gelände für einen Zeitraum von 10 Minuten bei einer jährlichen Überschreitungswahrscheinlichkeit von 0,02.

Figure 2: Wind Zones Map of Germany (Schmidt, 2012)

Although these standards and values exist, each bridge still has to have its individual planning. The location of a bridge varies, which leads to a variation in the territorial and climatic surroundings. Here wind and snow loads are important components which influence the statics of the bridge. For example the highest winds can be experienced at the coast and the highest snow loads in the mountains. Here, wind zone maps, also seen in Figure 2, of Germany have been created and specifically assessed to the location of the bridge. Important here is also what topography the location of the bridge is in, as the wind also can be affected by hills, open spaces or cities nearby. Meaningful here, the wind does not have that much of an effect on a bridge and normally effects the cars or trucks more, as they can experience sudden gusts of wind. The indicator precipitation also gets processed through for example the expected precipitation amount at the location of the bridge. According to this data, the number of rainwater inlets and their distances apart from each other is calculated. The construction of structures on the coast plays a very active part in the consideration of climatic data. Here a so called "Freibord" is specified. This is the remaining height between a certain water level (for example mean water level) and the lower edge of the bridge. Rising sea levels are thus already actively incorporated in the coastal areas, so that shipping can continue to operate properly (Wetzel, 2018). In addition smarter approaches such as a bridge that can open or adjust itself when the waters are higher to enable the passing for ships is also a concept which has been put into practice (Nebel, 2017).

As one can see climate data has always had an influence on the planning processes of bridges, however due to climate change, climate data and especially the accuracy of them is gaining more and more importance. With both the effect of the increasing traffic and the extreme events from wind gusts, temperature fluctuations, storms and strong precipitation events long term and sustainable adaptation plans are encouraged. This has led to a lot of research and a change into how climate data has been perceived. Rather than looking at the state and the past of climate data at a certain location, research has gone a lot into combining these with future predictions. In regards to bridges and roads, climate data has been used to make a road more resilient and adaptable to future climatic changes. Together with the Federal Ministry of Transport and Digital Infrastructure (BMVI), the Federal Highway Research Institute (BASt) has researched into adapting the road transport to climate change. Climate data here plays a detrimental role. Climate scenarios are available in quite coarse resolutions (approx. 200x200km). As the accuracy of these therefore is not efficient enough, regional downscaling is needed. These regional climate models are then blended with the road network in order to assess the affected infrastructure. The results of this data are then used for vulnerability or risk analysis. Further on the criteria for the endangered infrastructure gets determined and in conceding projects adaptation strategies get developed in order to decrease the vulnerability of the infrastructure. Here a lot of past research documents were overlooked once more with special interests in climate change risks for infrastructure and projections about the development of the climate. These findings were then discussed in interdisciplinary expert workshops and meetings. This was then displayed in cause effect chains and conceptualized in indicators for the fundamentals of the risk assessment and displayed in a matrix (Korn et al., 2017). The identified climate risks and the example of the matrix can be seen in Figure 3, exploring the main climate risks for bridges and other elements of the street infrastructure.

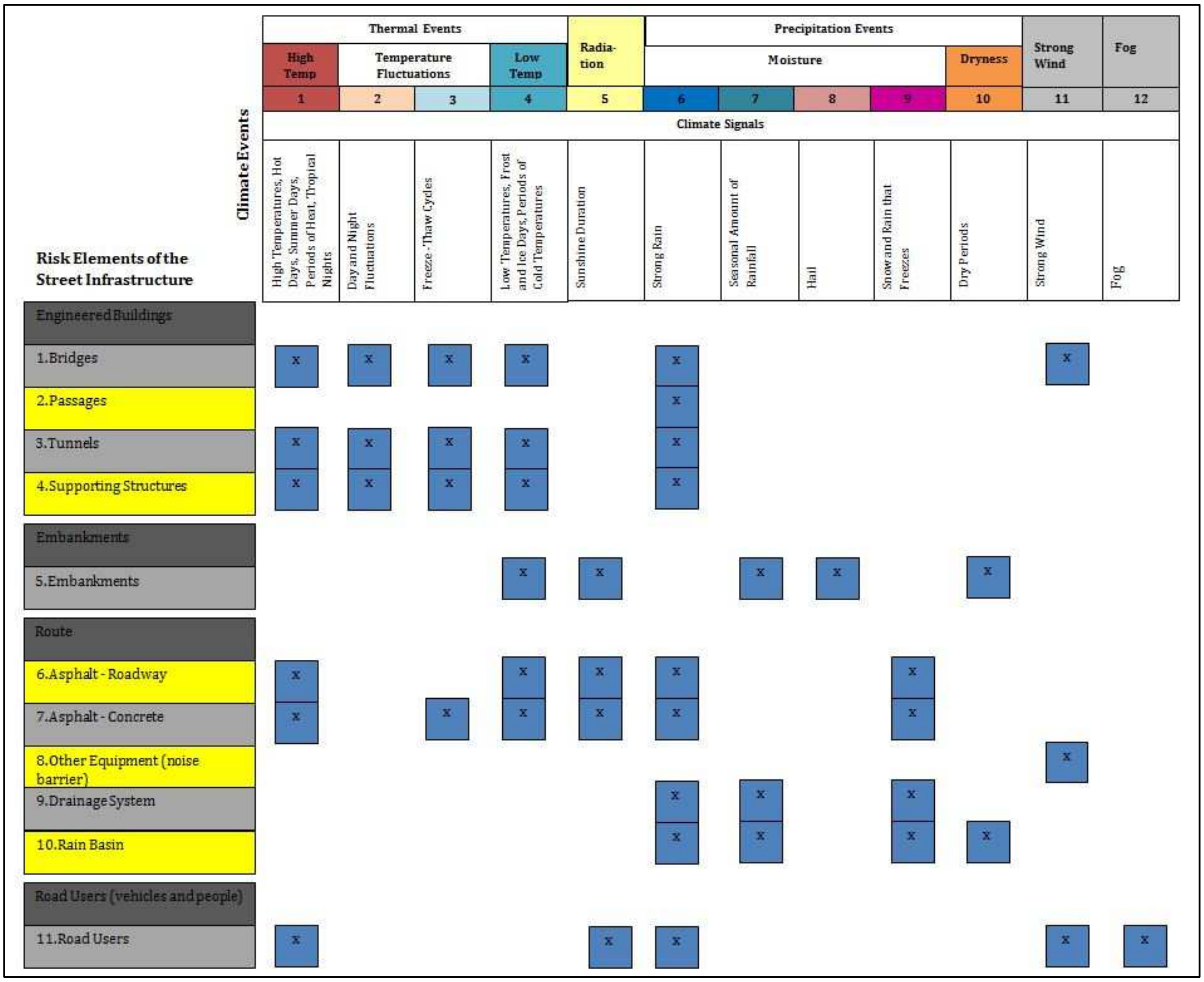

Figure 3: Matrix of the Risk Elements and Hazards of relevant Climate Events (translated from Korn et al., 2017)

An example of a concrete adaptation plan is the concept of a resilient road. The idea is that the road should adapt itself to the impacts of extreme events. The road should register flooding, snow, ice, wind and temperature changes and mitigate these effects through integrated flood drains, automatic heating and cooling and will be coupled with information systems for operators and road users (Auerbach et al., 2014).

Breaking this down, research and planning of bridges have had definite steps where climate data flows in. Firstly the possible climatic dangers of bridges have to be depicted. This is being done through risk assessments and vulnerability analysis. Anything that could lead to a decline in the components of the bridge is a potential indicator. Specific natural hazards that have been found were extreme weather situations, such as storms, hurricanes, floods, snowfall, heat or heavy rain. In addition short, strong and local events are extremely dangerous. As research has shown, this will increase in the future (Strauß, 2009). With the parameters heat, drought, floods and storms, an analysis of what effect this would have on the different materials and parameters of the road infrastructure, was undertaken. For the trend factor for the parameters heat, drought and aridness, research shows how periods of heat and hot days will increase. For periods of drought, there is seen to be an increase in frequency, intensity and duration. With these changes in climate data, the corresponding effect this will have on the specific infrastructure material or parts is assessed. Results show that during long periods of heat the construction of the bridge would be affected leading to deformations of the materials of the road ultimately leading to damages in the road. In regards to flooding, research displays how there will be more precipitation in autumn and winter, higher thunderstorm activity and risk of strong precipitation and hail. Simultaneously these events lead to flooding of streets and bridges and damaging of these as sediment transport might occur. Looking at storms and hurricanes which are seen to increase in intensity, the effects of the road infrastructure might be damages to bridge structures due to strong winds, secondary damages due to collapsed trees, etc. With these effects, adaptation strategies are reviewed for decreasing the vulnerability of the street infrastructure. Such strategies include the usage of heat resistant materials, wind protection walls and the optimization of water runoff paths (Strauß, 2009).

These examples show how the influence of climate data has transitioned to planning a bridge in the past to using data to plan for the future and adapt to the events which will occur due to climate change.

2.2 Hydropower Dams

“Water makes life as we know it possible” (American Museum of Natural History, n.d). It has always played an immense role in the evolution of the humans and has led to the existence of “hydraulic civilizations” thousands of years ago (Giesecke et al., 2014). In Germany regions of the highlands, Alps and big rivers are best possible conditions for hydropower use. Therefore over 80% of the hydropower gets produced in the south of Germany. The rivers Inn, Rhein, Donau, Isar, Lech, Mosel, Main, Neckar and Iller contain 86% of the total standard working capacity of large hydropower plants (Umweltbundesamt, 2015). However hydropower is very susceptible to climatic changes, as it highly relies on the flow of water. There are direct and indirect parameters affecting the hydropower dam. Most importantly elements such as air temperature, water temperature, salinity of water and shortage of water supply, evaporation, amount of precipitation and dry and wet seasons have a great effect on the amount of hydropower generation. In addition to this, the melting of glaciers also greatly affects the river runoff regime and simultaneously leads to a change in energy production. In regards to precipitation, forecasts show stronger rainfall at certain locations. The strong amounts of rainfall lead to higher amounts of water within very short time frames and hence put more pressure on the hydropower dam. When looking at a decrease of rainfall, the hydropower dam will suffer under a loss of energy production. Hence when looking at these two extremes concrete adaptation measures and planning, such as different designs in the drain water system, have to be put in place in order to decrease the risk of overflow and flooding and loss of energy production. However parameters such as temperature, sea level rise, floods, storm surges, river erosion and (tidal) wind create physical threats to the hydropower dam itself. With an increase of temperatures, certain metals or materials of the hydropower dam can deform or lead to failures. The increase of water salinity could potentially lead to more corrosion of machines and structures. In regions of the coast, climate projections display an increase of wind speed, which might lead to higher storm surges, either leading to breakages in the dam or failing of the dam (Kahn, 2012). Due to these vulnerabilities of the hydropower dam, the planning and assessing therefore has to be very precise and accurate.

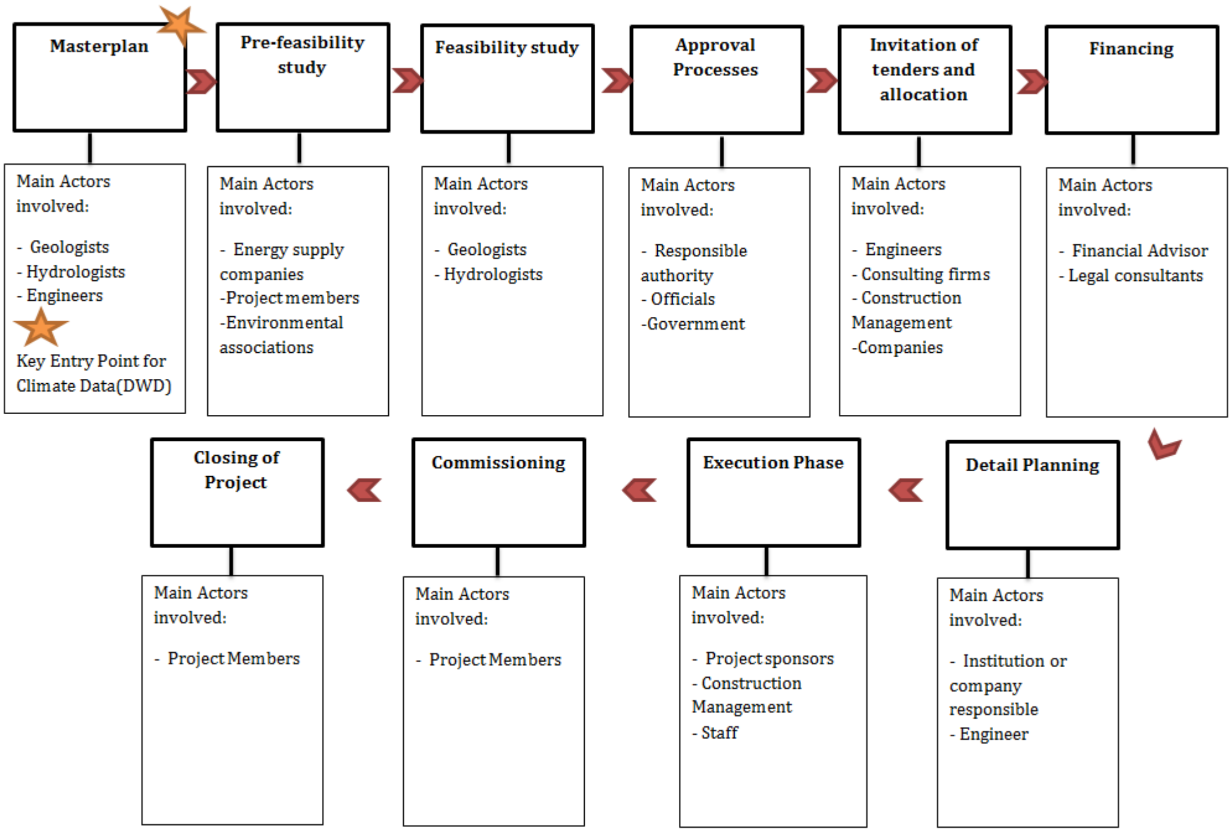

Figure 4: Flow Diagram of Planning Process of Hydropower Dams (Giesecke et al., 2014)

The process of planning and implementation consists of a number of steps and phases, codes and standards. An illustration of this can be seen in Figure 4. The entire process from the idea phase, including the requirement clarification, to the planning and the approval and start of construction up to the commissioning, can take four to ten years, depending on the complexity of the project. Firstly within the scope of the "Masterplan" (Potenzialstudie), the ideas and intentions for an individual hydropower dam are determined and realized along a section of water. Here data from measuring stations is used to gather information about the level of the river in certain years. If this data isn't enough precipitation data or radar data is then intersected with temperature to calculate the evaporation and calculate the amount of extra runoff the river has (Heimerl, 2018). With the help of a GIS software, hydrological and topographical data is then used to measure the potential for the hydropower at the given site. Secondly the Pre-feasibility study (Vorstudie) looks into the critical points of the planned location through the requirement clarification and study of the economic feasibility. In accordance to that, the feasibility study (Projektstudie) should finalize all the previous studies and display how economically beneficial and useful the project would be. This step analyses the previous steps in more detail and more specific data is needed here. Up until now this can take one to four years, depending on complexity of the project. Subsequently the approval procedures (Genehmigungsverfahren) can only be enforced once each federal state´s guidelines and standards are incorporated. The rule here is that, in order to have the least amount of risk and time consumption, a close coordination has to be evident between the specific authorities and the others involved. An example of the project members currently involved can be seen in Figure 5.

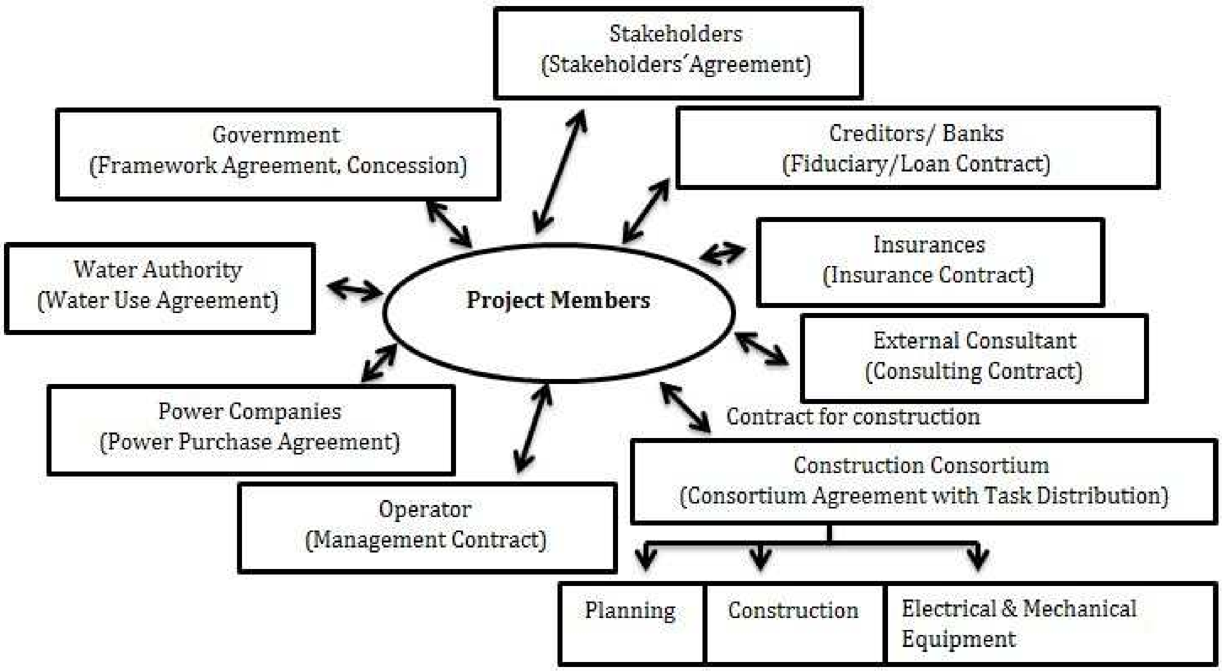

Figure 5: Project structure
(translated from Giesecke et al., 2014, pg.52)

These actors have a regular communication regime enabling a clean run through of the project in most cases. Following this the project then undergoes an invitation of tenders and allocation (Ausschreibung und Vergabe). The important part here is that the project has to be displayed in a very detailed description in order to know what exact batches and parts have to be ordered. In addition it has to be made clear who is in charge for meeting the technical and hydropower regulations. In this phase it is important for the principal of the project to decide the key roles responsible for each part of the project. Engineering offices, consulting firms, site or construction supervisors have to be allocated or contacted if desired. Different options for the main team for the project are openly displayed and critically examined, not only under financial points but also and more importantly under the experience and competences. The last part of this step is the inclusion of the norms, codes and standards. These are subsequently amended specifically to the project, which secures safety in case of litigation. In order to advance to a successful implementation of the project, the financial aspects also have to gain a lot of consideration, by making points of contact with banks and insurances well in advance. Furthermore the project has to undergo individual and detailed planning which takes the local circumstances into account. In this step, each construction component has to be examined thoroughly and optimized to the specific project and site, as no hydropower dam is provided in mass production and can be transferred anywhere. The “design as you go” principle allows the further run through of the project to concede smoothly. The idea here is that next to the detailed planning, the execution of the project also gets planned. Before the execution of the construction works, there should be a document where the possible effects of the entire site are displayed. In accordance to that, under the risk assessment, the flood risk and prevention has to be assessed, in order to reduce the risk of damage and harm to the project and surroundings. As the determination of the flood levels at the construction does not have any codes and standards, data such as time of the construction, season (dry or wet periods), type of precipitation events and risk and damage expectations of the different construction phases is used. The last two steps of this process are the commissioning and closing of the operations. With the finished works of the construction and assembly works a run-through test is scheduled, which should test that all components work flawlessly. At last all completed plans should be finalized and saved in a written form, for future reference. Already during the execution phase, the financial statements should be updated, however with this last step, the final invoice should be completed, in order to round off the project completely (Giesecke et al., 2014).

With the climate changing, this process has been adapted in order to meet the regulations for future needs. Due to this climate data has taken more importance in the planning processes of hydropower dams. GLOWA Danube, KLIWA, KLIWAS, WASKlim are research projects under the UBA, which focused on the water industry of Germany. Climate data that is used here is specifically winter and summer precipitation. Regional downscaling is used to get a better picture of a specific region. Examples of climate change scenarios used for these projects was that the temperature in the summer/winter of 2021-2051 would increase by 1°C and that the precipitation in the summer for the years of 2071-2110 would decrease, but in the winter however increase. With this data, the run-off process of three different river run-off regimes was investigated (Wolf-Schumann & Dumont, 2012). The Federal Institute of Hydrology (BfG) uses the raw data from the DWD, places that in their own climate model and generates accurate projections of the runoff regime (Walter, 2018). This data is then used to assess the effect of the river runoff regime change on the hydropower. From the state of the climate research model discharge scenarios for different locations where examined. Through this, the change in energy production was investigated. The outcome of this was that in the second half of the 21st century there will be a decrease in the production of energy generation of 1%-4% and in the distant future a decrease of up to 15%. On the basis of these results, model discharge scenarios for different locations where examined and changes in energy production in hydropower plants in correlation to this was tested. With the outcome of these tests, adaptation measures and operational management plans were developed, which are incorporated and accounted for in the risk assessment for example, such as through changing the run-off regime through a better water storage, useful runoff parts can be held back in order to open them, when periods of low runoff occur. These storage and holdback settings lead to a better energy yield and adaptability (Wolf-Schumann & Dumont, 2012).

2.3 Coastal Protection

On the contrary to bridges and hydropower dams, coastal protection has always been an act of defending oneself to climatic changes and events such as strong storm surges and flooding. Already in the early years, inhabitants of coastal regions have tried to protect themselves with all available resources. Planning and constructing was not easy back then, due to the limited availability of knowledge and resources, leading to frequently damaged or destroyed dams or dykes. Therefore key climatic risks associated with the durability of a dyke are strong winds, storm surges and a rise in the sea level. The point here was that they could not assess how strong the next storm surge would be and how the dam or dyke has to be built in order to prevent the event from harming livelihoods (Meurer, 2013). Although coastal protection has always played a big role in protecting ones livelihood and land, more and more research is going into how climate data can help us protect our coastal regions against climate change. When knowing what to expect, dykes and plans can be implemented accordingly. Here climate research is playing a key role in finding adaptation options for dyke construction (Wetzel, 2018).

Although coastal protection in Germany is mainly the job of the federal states, the usage of climate data is principally the same. Climatic trends often are associated with numerical simulations (Schmidt, 2001). Therefore it is important to have a sustained amount of long time series and records of climate data and flooding events. In addition data about the increasing and expected sea level is needed to evaluate the future effects which might still occur (Hirschfeld et al., 2012).

The Integrated Coastal Zone Management (ICZM) of Germany is an informal management approach who´s aim is through good integration, coordination and communication to develop sustainable strategies for coastal protection and is a process which should act as a model for all areas in planning and decision-making. It acts as an informal, interdisciplinary tool that can support the preparation and implementation of formal spatial plans in the coastal and maritime areas. The ICZM however does not act as an individual planning and decision-making instrument which implements specific subject and individual interests. That is the job of the individual federal states (Hülsmann, 2017). There are three federal states in Germany, which focus on coastal protection.

Schleswig-Holstein, Mecklenburg-West Pomerania and Lower Saxony, and the actors responsible for coastal protection work together with the North German Climate Office (Norddeutsches Klimabüro), DWD, universities and many other authorities to generate accurate assumptions and data of climatic changes, for their specific region. The bases for any of the research are climate calculations, which are combined with dynamic regional climate calculating models (Umweltbundesamt, 2017). A product of this is the North German Climate Atlas, as seen in Figure 6 and displays a map of the north of Germany, its coastal regions and the change of temperature. This website enables a visualization of specific parameters and their future scenarios and effects on all North German Federal States.

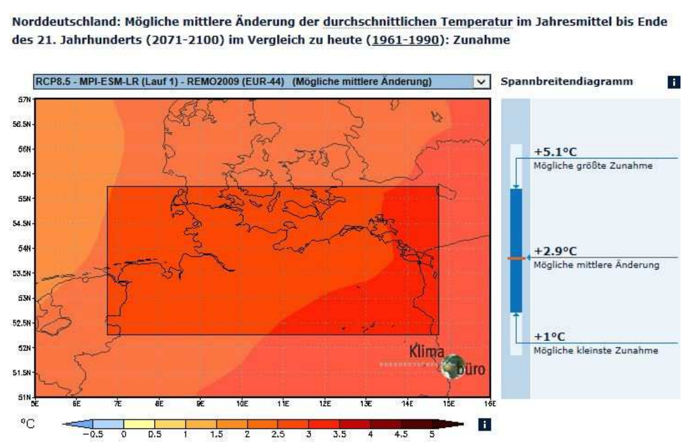

Figure 6: North German Climate Atlas of Schleswig-Holstein, Mecklenburg-West Pomerania & Lower Saxony (Norddeutscher Klimaatlas, 2018)

There are 12 regional climate scenarios. Climate parameters such as wind, precipitation and temperature are most important. These then are narrowed down to even more distinct and specific parameters (Norddeutscher Klimaatlas, 2018). In addition and to set this scene in a more international agenda, Schleswig-Holstein and Mecklenburg-West Pomerania are part of the BALTEX research network, a network of all Baltic Sea regions, which researches in areas of how precipitation and runoff volumes of rivers changes in the future, what effect these changes will have on the infrastructure or ecosystem and which interactions exist between the individual components of the system. Now current research displays that the Baltic Sea region has warmed up by 0.85°C in the past century however this differs in regional aspects. In a year there are now ten days more summer days (warmer than 25°C) and 20 less frost days than in the 1950s. In the 20th century the total amount of annual precipitation is said to have increased. As a result of this and other generated data it is safe to say that warming of spring and less rain in summer, along with increases in stronger rain in winter and increase in melting ice, leads to a rise in sea level. In return, this results in more storm surges. Climate data here is used to act as a basis for climate scenarios which then get converted into the possible effects and the result these effects then have on the ecosystem, infrastructure and living conditions (Meinke & Reckermann, 2012).

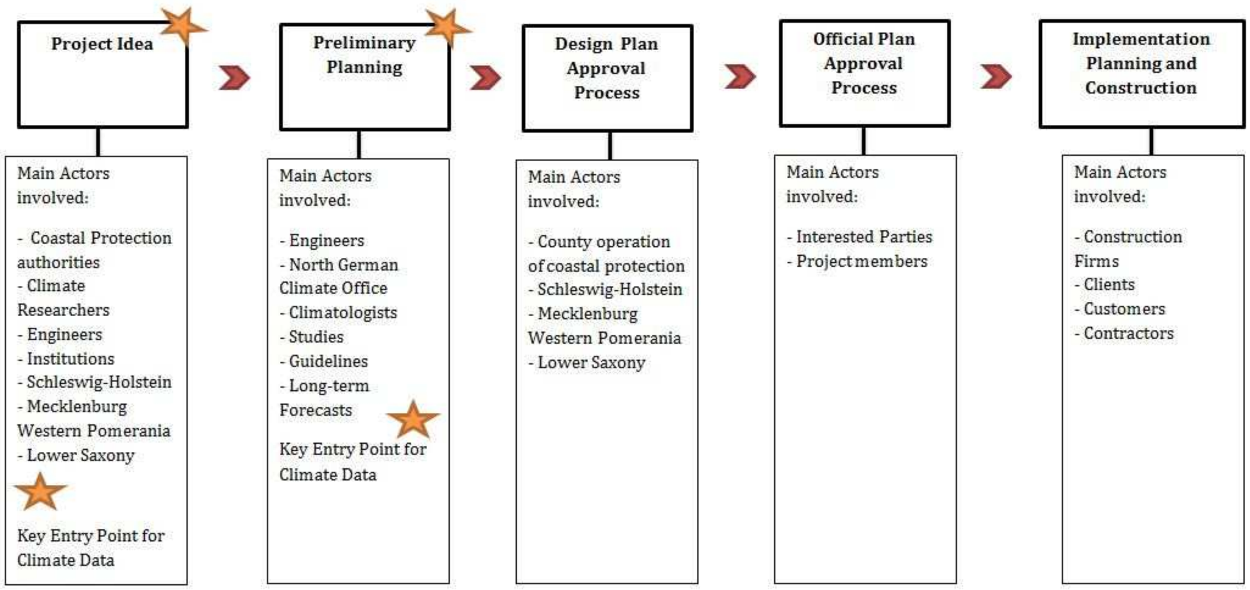

Figure 7: Flow Diagram of Planning Process of Dykes (Coastal Protection Measures)

The key entry point for climate data in the planning of coastal protection measures such as dykes mostly flows into the project idea and gets further assessed in the preliminary planning, as seen in Figure 7. Climate data here acts as a key motivator to even develop a project idea and the knowledge that a dyke has to be built, however also determines what the width and the height of a dyke should be, symbolized by the star in Figure 7. Here climate researchers, coastal protection authorities, engineers and federal states work under close coordination to enable well planned adaptation measures. Codes and standards here get accessed as well however dykes need to be customized individually and hence demand a bigger leeway (Pohl, 2013). Although this planning process seems quite similar to bridges and hydropower dams, as these are all engineered structures, climate data, especially projecting into the future is and has already gained more importance when planning coastal protection measures.

2.3.1 Schleswig Holstein

Actors in charge for coastal protection in Schleswig-Holstein have developed a systematical climate monitoring which incorporates specific indicators associated to climate change effects on the state. Firstly the UBA completed a study which looked into indicators for the state which display changes and effects of climate change. One of these indicators was coastal protection. With the results of previous research and the help of the North German Climate Office, the studies came to the conclusion to use an extra width of 0,4m and 1,4m in the dimensioning and construction of dykes.

Basis of this finding was the results of the expected storm surge water levels by 2100 (MELUND, 2017). However it is very unsure of what exactly will occur, therefore options have to stay flexible and the use of so-called "No-Regret-Options" should be incorporated. These are options which should be used as precautionary measure however if they don't work, they should not be regretted (Landesportal Schleswig-Holstein, 2017). However, knowing climate data and calculating possible scenarios of future events, calculations can be made for strengthening the dyke.

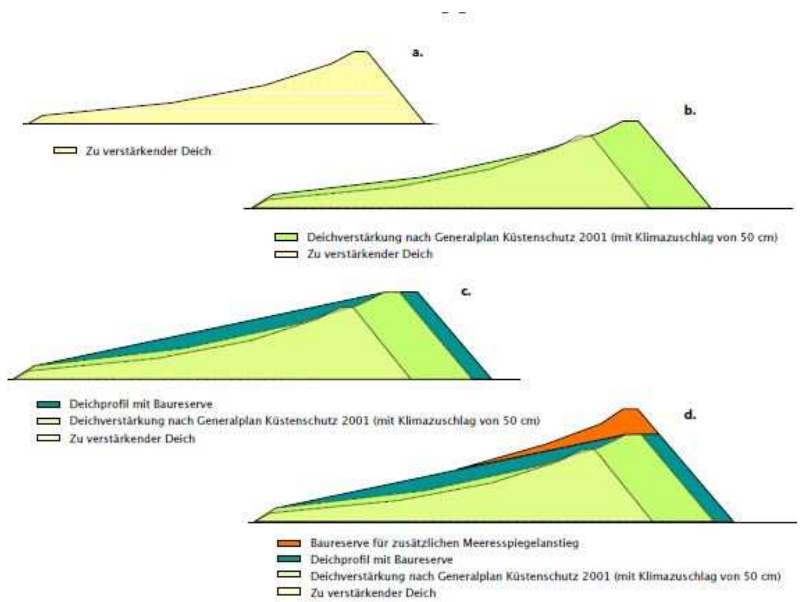

Figure 8: Figure 7: Dkye Strengthening after New Findings (MELUND, 2017)
Explanation: different stadiums of the dyke planning with more surcharges according to different variables.

Figure 8 shows an example of how individual steps are incorporated to make the dyke resilient towards the effects of climate change. When planning a dyke, a climate surcharge of 0,5m is included. The tip of the dyke then also becomes adapted from 2,5m to 5m in width. With these measures an increase of 0,5m of sea level rise is adapted to (MELUND, 2017).

2.3.2 Mecklenburg-West Pomerania

In Mecklenburg-West Pomerania coastal protection runs through a long history of destruction and re-building of dykes. The coast of this state has been transformed many times during the glacial periods. Out of the dynamical character of the coast, technically there do not have to be any adaptation measures. Only with the usage of the coastal regions by us humans is when adaptation measures had to be taken. These include coastal protection measures ensuring for middle or long term reduction of shore decline or loss of land and measures against flooding through storm surges. Principally the way forward here, was to investigate into the coastal situation, both in a hydro dynamical way but also in a topographical way to receive a clearer picture of what the situation is like. Under the hydro dynamical situation tide, currents and extreme weather events were considered. Floods due to storm surges are caused by strong winds or storms from the north. Then strong flooding events due to storm surges where looked at since 1872. With looking at the reoccurrence of floods and events and understanding how future climate changes will affect extreme events and the water level, measures for adaptation have been developed. Research shows that with the tip of a dyke being 3,5m in height, they have to be 40 to 45m in width. Hence this shows that dykes need specific engineering in order to withstand the future requirements (Seidel, 1993).

2.3.3 Lower Saxony

Similar to Schleswig-Holstein and Mecklenburg-West Pomerania, Lower Saxony has used climate data and established a 50cm precautionary measure when planning and building dykes. In addition these dykes are built up in a way that if necessary, they can be raised. Here the knowledge from storm surges from 1962 and 1976 in addition to new research results act as the basis for functional and constructive design in coastal protection measures. Swell, tide currents and wind lead to a dynamic usage of the area. The constant changes of these affect the coastal protection measures constantly (Generalplan Küstenschutz Niedersachsen/Bremen, 2007). Due to these effects, the government commission of Lower Saxony has established a systematical and comprehensive analysis of the consequences and challenges to be experienced by climate change. Results showed that there will be a higher danger of storms and intensity of storms which in return will affect buildings, and infrastructure. In 2008 this led to the establishment of a commission of 42 members responsible for developing strategies for climate protection as well as adaptation. For smooth coordination and accompaniment of the measures and strategies, the interministerial working group (IMAK) "Niedersächsische Klimapolitik" got established in 2013 (Umweltbundesamt, 2016).

General Conclusion Coastal Protection

As one can see all three states might have different approaches or history, however mainly use the same ideas and concepts of protecting themselves to climate change and flooding. Sustainable and well planned coastal protection is of the upmost importance to inhabitants of coastal regions and a well running economy. Hence it is important to not only look at the individual area of responsibility, but to exchange information and knowledge. In addition information about the past and present helps us assess what will happen in the future and hence plan accordingly. As all states work individually when constructing a dyke, there is a lot of exchange of information in regards to climate data and findings of research. For example there are regular meetings of working groups between coastal protection authorities and the Technical University of Hamburg and the University of Rostock under the overall project called RADOST. This information then also gets exchanged on the international scale (RADOST-Verbund, 2014).

3. Conclusion

Climate data is taking more and more importance in the planning processes of bridges, hydropower dams and coastal protection in Germany. Here especially the accuracy and persistency is most important. With knowing data from the past and present, the future can be adequately assessed. In regards to bridges, the general way climate data flows into the planning process is that DIN norms are used and define how a bridge has to be built. These include specified values. However specific maps and data, such as wind maps, are then further assessed for a bridge location which then enables the engineers to calculate the wind, precipitation and the temperature load which can be expected on the bridge. This data then acts as the basis for the start and implementation of the construction phase. For hydropower dams the river runoff process is the most important data the engineer needs. If necessary the precipitation data at a given site or location will be assessed as well. This is particularly done in assessing the future energy potential of a given site. In coastal protection, wind, precipitation data, sea level rise and past flooding events are used to assess the height of specific dykes in order to protect livelihoods from storm surges and detrimental flooding events. In many cases raw climate data is intersected with certain hydrological or other models which give a simulation of future outcomes, the potential energy yield at a given sight or the situation of currents.

The important part here is that climate data is used to plan and mitigate the risks of these infrastructure types; however each sector has its own differences in regards to the way climate data is assessed and accounted for. For example with bridges, climate parameters are seen as a danger and an indicator which affects the durability of the building. In regards to hydropower dams, climate data in a way acts as a basic requirement for the planning of, if and how a dam is built. It influences the energy yield and in some way also the durability and profitability of the dam. At last for coastal protection, dykes are built for the protection to climatic changes, so in other words only built due to the impacts of climate events such as flooding or storm surges. All in all however a failure of all infrastructure types, leads to an effect on us humans and therefore we heavily rely on the good planning and incorporation of climate data of the future.

To sum this up, climate data plays a great importance in the planning processes of bridges, hydropower dams and coastal protection in Germany. Climate data mainly takes its part in the preliminary and design planning of the specific construction. In addition the climate or climate change per se has a big influence into the existence and dominance of codes and standards and when climate information is taken into consideration. At current times Germany is in the process of assessing climate change impacts in planning processes and standards and norms. Specific management plans have been incorporated which for example in hydropower dams change the run-off regime through a better water storage, which can be held back and opened when needed. As one can see a lot of research is going into the idea of using climate information as a source to adapt certain infrastructure types to our future requirements and using smarter approaches. As climate data is so detrimental for sustainable infrastructure, it is crucial to have the most accurate and reliable information available. In order to adapt to the future the general way of planning is using raw climate data, insert this into projections or models in order to then generate a vulnerability or risk analysis. This in return then leads to the assembly of adaptation strategies and to longer lasting and resilient infrastructure.

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http://cdn3.spiegel.de/images/image-345866-galleryV9-tpjv-345866.jpg

Image 2:
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