Climate adaptation services and the factors influencing their usability

A comparative case study to understand the usability gap

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Sincerely yours,

Upasana Mukherjee

PREFACE

This research initially stemmed from my passion for understanding climate services and improving them for end-users to make informed decisions in order to adapt to climate change. As the world is facing the drastic impacts of climate change, there is a dire need to adapt to these consequences. Determining the factors that could potentially influence the usability gap between the climate services and the end-users will help the involved stakeholders to make decisions that are suitable for the society and the environment in order to adapt to climate change. Moreover, it is not only my passion to find which factors influence the usability of climate services in a particular region, but also compare the climate services and its potential usability gap in different regions and cities in Europe.

Therefore, by conducting this research and comparing different regions in Europe will improve the climate services for the end-users and help them understand the effects of climate change in-depth, how to adapt to these changes, what measures can be taken, raise awareness not only among the decision-makers but also the citizens. It will also motivate the end-users to participate and build a sustainable and resilient surrounding for a better future and a better quality of life.

Thus, my interest/ passion for this topic as a master student of Spatial planning-Cities, water, and climate change at the Radboud University, gave me the motivation to conduct this research successfully.

SUMMARY

The world today is facing various phenomena, such as impacts of climate change, urban sprawl, economic crisis, and many more, which in turn has affected not only the quality of life but also our environment. The central objective of the study is to analyze and understand the factors that influence the usability gap between climate adaptation services and the end-users, which could potentially influence the decision-making process.

By using qualitative methods for analysis, six factors were derived based on the theories, which influences the usability gap between climate services and the end-users in each case study. The six factors derived are the type of information provided, visual representation, information framing or goal and purpose of the climate services, type of communication, spatial/temporal (action-oriented) aspect, and target audiences, all of which are the information needs and demands of the stakeholders.

To understand these factors, a theoretical analysis was done. In order to make it as practical and close to ground-reality as possible, an explicit comparison between five case studies in Europe was carried out. Thus, a case study strategy was selected to conduct this research. The case study strategy included document analysis, surveys, and interviews with relevant stakeholders and experts from all the five case study sites (Flensburg in Germany, Arvika in Sweden, Larvik in Norway, North Brabant, and Drenthe-Fluvius region in The Netherlands). To understand the information needs of the stakeholders as well as bridge the usability gap between the end-users and the climate services, a stakeholder/expert analysis was conducted.

In conclusion, it was observed that all of these six factors influence the usability of climate services. It was also observed that in practice, all the aspects of the DESTEP model (the type of information) and the Spatial/temporal (action-oriented) information might not be necessary for the climate services, as stated in theory otherwise. If all the information provided by the service tailors to the stakeholder's demands, then the usability gap will reduce. Additionally, many other factors also exist and influence the usability of climate services. Thus, further study can be conducted to explore other factors and improve the usability gap.

Improving upon these factors could be essential for the end-users to understand climate change impacts in-depth, spread awareness, build more connections with other stakeholders and participate actively to build a sustainable and climate-resilient city for a better future and liveability. This master thesis is conducted in collaboration with my internship at Deltares, The Netherlands, in the project called “EVOKED.”

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1. INTRODUCTION TO THE RESEARCH

1.1. Introduction (research problem statement)

Climate change is one of the most significant issues that is causing great concern in Europe and all over the world (Ludlow, 2009; Morozova, 2018). Over the last few decades, the European countries had to face multiple phenomena such as impacts of drastic climate change, urban sprawl, global warming, economic crisis, the spread of new technologies and many more, which in turn has affected not only the quality of life but also the environment (Morozova, 2018). Since climate change is one of the biggest challenges that all the countries in the world are now facing, it is essential that we, as humans, adapt to the changing climate and also take preventive measures to control the effects of climate change. The consensus that many of the experts reached relates to the unquestionable fact that the Earth is getting warmer day by day, which is caused by human CO2 emissions emitted in the air. Thus, there will be severe consequences if this problem is not solved soon (Henderson, Reinert, Dekhtyar & Migdal, 2018).

Climate adaptation is associated with rising sea levels and an increase in precipitation, which causes flooding. However, water scarcity and drought can also have a significant impact, especially concerning freshwater supply for agriculture and nature. Along with flooding and droughts, there is also an increase in the level of heatwaves, especially during the summers causing heat stress in many cities. These issues are visible in both rural and urban areas of the world (Yiannakou & Salata, 2017).

With these changes, there has been a shift in the spatial planning of the cities to adapt to the changing climate. However, these shifts are still an on-going process, which may take decades for the cities to become climate resilient (Yiannakou & Salata, 2017). Spatial planning or urban planning, which is a prominent field nowadays, is emerging as one of the policy areas that can influence both adaptation and mitigation measures towards climate change (Yiannakou & Salata, 2017). Even though both adaptation and mitigation measures are essential for sustainable development, this research will mainly focus on adaptation measures.

In order to implement climate adaptation strategies in different cities of the world, there must be awareness and knowledge about climate change impacts and effects, for the target audience such as different stakeholders who are responsible for taking actions towards adapting to climate change. In today's world, a large amount of climate data and information is available; however, most of this data is not efficiently used (*European Commission*, europa.eu, n.d; Lemos et.at., 2012). Thus, there is a growing demand for translating the existing climate data and information into user-friendly and knowledge-intensive customized tools or services (*European Commission*, europa.eu, n.d; Lemos et.at., 2012). These services or tools are called "climate services or climate information services," which are used by the end-users to adapt to climate change. With the help of these services, the cities can become more climate-proof (*European Commission*, europa.eu, n.d; Lemos et.at., 2012). To boost the implementation of adaptation towards existing or future climate change risks, the decision-makers can use this knowledge-intensive service to make informed decisions (*European Commission*, europa.eu, n.d; Lemos et.at., 2012). These climate services not only strengthen the awareness and build the resilience towards impacts of climate change but also improve the global market demand for climate adaptation services or strategies that can be implemented to tackle the risks of climate change (*European Commission*, europa.eu, n.d).

According to the EU (European Commission, 2015), climate services not only include information on climate change impacts or effects, but also the potential solutions or strategies which can be presented in terms of projections, trends, advice, development, and evaluation of solutions. These services can be based on both modeled data as well as observational data (Bowyer et al., 2014). According to many researchers, the climate services can be defined as, "*the development and/or provision of climate information and knowledge to support users' decision-making through tools, websites, and tailored products"* (Hewitt et al.,2012; Vaughan & Dessai, 2014; Bruno Soares et al., 2018, p.6). The climate services should consist of useful data based on the social, ecological, economic, technological, and political impact that can occur in vulnerable areas due to climate change. Moreover, such information is often used for educating, raising awareness, bringing in changes in social and cultural values, and increasing a motivating attitude to take the initiative towards climate change among the end-users primarily (Medri et al., 2012; Orr et al., 2015; Brasseur & Gallardo, 2016). Most of this information comes from the official sources such as the knowledge institutes and researches done by the government actors, a mix of different stakeholders, or

by participatory means by the citizens (Hegger & Dieperink, 2014; Meadow et al., 2015; Wehn et al., 2015; Star et al., 2016).

Now that the definition of climate services is understood, it is also essential to understand to what extent the services are being used by the end-users and if they are delivered effectively. Hence, communication of such climate information is another crucial aspect in order to involve the end-users in an effective and productive manner, to improve the usability of climate services. According to Moser (2010), communication of information focuses on the intended goal; intended audience, information framing, used formats, and communication channels. These aspects are essential as a wrong focus may lead to so-called 'usability-gaps' between the offered information and the information-need of the user (Lemos et al., 2012).

A recent study conducted by Weaver et al. (2013) states that there is an underutilization of climate models or services as tools for supporting decision making. This usability gap is, in turn, slowing the process of developing and implementing informed adaptation measures towards climate change. According to Weaver et al. (2013), there are two causes for this underutilization. The first reason is the information not being tailored according to the stakeholder's demands, hence slowing the process of decision making and implementation of adaptation measures. The second reason is the knowledge produced may not lead to actionable knowledge, as there are many other institutional arrangements or external factors involved, such as actors, the rules, resources, and dominant discourses that are not considered in the climate services. This makes it difficult for stakeholders to act towards climate change in an informed manner (Weaver et al., 2013).

Scientific studies like this give a strong motivation to understand and improve the usability gap between the climate services and the end-users so that the services can be used effectively and provide useful information on climate adaptation measures. Hence, this research focuses on exploring and identifying the factors influencing the usability of climate services in different cities. To gain a better understanding of the usability gap, different types of existing climate adaptation services for different cities in Europe will be analyzed in this research. The analysis will be done based on the factors influencing the usability of climate services in relation to the information needs of the stakeholders. It will also result in finding solutions or recommendations for improving the usability of climate services so that these

climate services can potentially contribute to implementing spatial planning measures and policies. All these influencing factors and the usability gap will be further explained in the next chapter in detail.

1.2. Research aim and question(s)

The main goal of this master thesis research is to understand and analyze which factors influence the usability of the climate adaptation services at the study sites (Sweden, Norway, The Netherlands, and Germany). The analysis is made based on the potential influencing factors in the climate services, which leads to the usability gap, such as the target audience, information purpose/ goal, and framing, spatial/temporal (action-oriented) information, type of information (demographic, ecological, social, economic, technological, and political aspects) as well as the visual representation. These factors can be used to understand the barriers and in turn, reduce the usability gap of the climate services for the end-users. Understanding the factors that influence the usability of climate services will help in developing strategies to tackle climate change, increase awareness and help in making informed decisions towards by the stakeholders to build resilience in the climate affected areas.

To reach the goal, the main research question of this paper is as follows:

Which factors explain why climate adaptation services are (not) being used by end-users to develop adaptation plans, and how could the usability of these services potentially be improved if needed?

Following are the list of questions that will help in answering the main research question for this research strategically:

Sub- research questions:

- What are the existing climate adaptation services available at the study sites?
- Who are the local/ regional or national stakeholders involved in the implementation of climate adaptation strategies to build resilience and adapt to climate change?
- To what extent are the climate services being used by the end-users?

- Which are the factors that influence the usability of climate adaptation services?
- How can the usability gap between the climate adaptation services and the end-users be potentially improved?

In order to answer the research question, a case study strategy is selected to conduct this research, which includes several research methods such as desk study research of existing documents, literature reviews, and theories. Furthermore, primary research is conducted by attending workshops, taking interviews, and surveys with experts in this field for each case study site. First, a review of the literature will be made, followed by the case study strategy to analyze the case study sites in terms of climate change impacts on the study sites, existing climate services and the potential factors influencing the usability of a climate service. Interviews and surveys with relevant stakeholders and researchers will be conducted to understand the information needs of the stakeholders or end-users.

Additionally, this strategy will also help in determining the solutions for improving the climate adaptation services to increase awareness among the end-users and motivate the stakeholders to implement adaptive climate strategies based on the information and the data available in these climate services in order to adapt to climate change and build resilience. In general, it will also inform the public about what needs to be done, when, and where in terms of adapting to climate change. The following strategic flow chart below depicts the outline and the structure of this thesis.

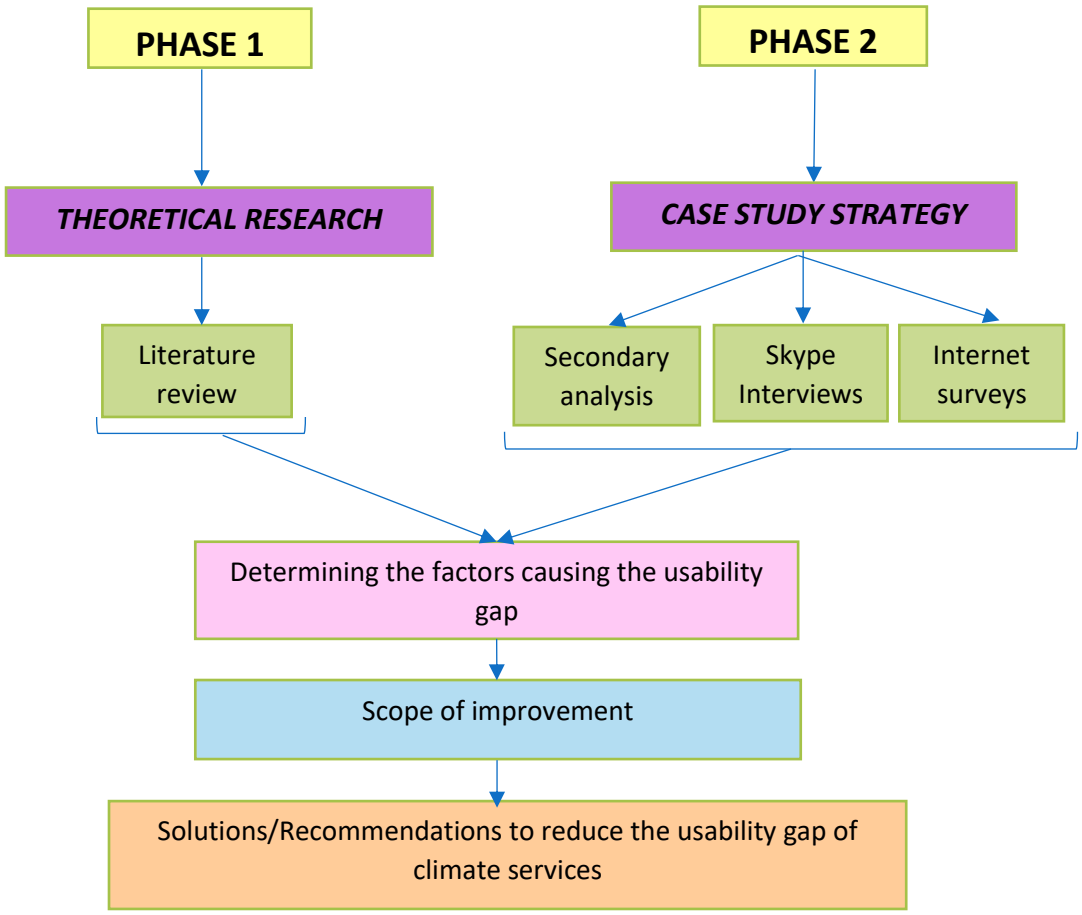

Fig 1. Thesis Outline (Source: author)

1.3. Societal relevance

There has been a substantial amount of scientific evidence which indicates that climate change is occurring to some extent due to society's greenhouse gas emissions. Many countries in Europe are taking quick measures to tackle climate change, such as mitigation and adaptation strategies (Diş, Dymén & Lange, 2011). Climate change mitigation strategies were applied long before adaptation strategies came into existence; however, these mitigation measures have been unsuccessful until now. Different patterns of settlement, the spatial infrastructure of cities, land use allocation, lifestyle, and consumption behaviors, all influence the combined effect of climate change (Yiannakou & Salata, 2017). Thus, many researchers, planners, and policymakers are now emphasizing climate adaptation measures by shifting its dimensions from mitigation strategies. These adaptation measures have now been incorporated in urban spatial planning for cities, especially in Europe, which are vulnerable to climate change (Diş, Dymén & Lange, 2011). For example, heat stress, drought, and flood risk management. It is not just the government itself that is developing the city area, but a combination of different actors or stakeholders such as NGOs, private businesses,

citizens and many more are involved in the sustainable development of a city (Biesbroek et al., 2011). Moreover, in order to make adaptive climate decisions to implement the strategies, there are many governance issues or barriers for adaptation (Biesbroek et al., 2011). Such as conflicting timescales, conflicting interests, lack of financial resources or technology, unclear division of responsibilities or tasks, fragmentation between the level of governance or uncertain societal costs, and future benefits (Biesbroek et al., 2011).

Thus, it is essential to focus on climate adaptation strategies in terms of urban planning for cities to tackle climate change. Also, it will not only improve the socio-economic status of the country by creating more job opportunities but also increase its liveability and awareness of climate change among residents through sustainable development.

The European Commission's Research and Innovation policy and investments are trying to focus on the emergency of climate services in Europe which will also drive the market to implement climate adaptation strategies by providing a framework that will not only increase awareness among the end-users but also generate economic value from the climate information or data and models from the ongoing research (*European Commission*, europa.eu, n.d). This scientific data will also help in providing benefits and solutions to face the challenges in society related to climate change (*European Commission*, europa.eu, n.d). Furthermore, climate services are expected to result in increasing the quality and effectiveness of decision making such as resilient infrastructure, future investments and business opportunities; but also help in adapting to climate change in a more cost-effective manner which will, in turn, make the European economy more competitive (*European Commission*, europa.eu, n.d).

The findings from this study will also relate to the research recommendations made by Vaughan et al. (2016) who suggested in their study that more research should be done on how climate information data is communicated, what kind of information is needed by the stakeholders based on their demand, how the information can be easily accessible and interpreted to make decisions based on climate adaptation measures and what are the capacities/ tools that are used regarding climate change adaptation.

1.4. Scientific relevance

Apart from the social relevance, the present research has few scientific relevances. There is a lack of understanding of why certain climate services are being used or not used and what are the reasons behind the usability gap of the climate services among the end-users. Furthermore, topics such as public and private sector involvement, the roles of these actors, business versus welfare, etc. are poorly described within the sustainable urban development theories. Hence, this research will help in filling the potential usability gap of the existing climate services in the study sites based on the information needs, information framing, communication, the involvement of the stakeholders and the other factors that potentially influence the usability gap of the climate services, in order to increase awareness and motivation among the end-users to implement climate adaptation spatial strategies in climate change affected areas.

According to researchers, climate services are considered to be a timely production that consists of relevant climate information for the decision-makers; however, it has been continuously reported that there is a usability gap between these climate services and the end-users (Alexanders & Dessai, 2019). To address this issue co-production of climate services among the knowledge providers and the end-users is essential, which will help in tailoring the information according to the end-users in order to make informed decisions and implement climate adaptation measures (Alexanders & Dessai, 2019). The researchers also stated that aspects like the behavioral intention, collaboration among end-users, end-user's perception of the climate service, management, and service marketing to increase awareness are also crucial factors that could lead to the usability gap between the climate services and the end-users and thus, needs to be improved.

Even though there is a constant growth of knowledge available for the global climate change systems and the dynamic interaction of the human actives, there are still many gaps or lack of information needs which should be tailored to the end-users as well as their demand and supply based on the available or newly produced data (European Commission, 2015). There is an abundance of climate data in today's world; however, a lot of this information is not used by the stakeholders to make informed decisions while applying climate adaptation measures in the risk-prone or vulnerable areas (European Commission, 2015). Many such studies recommend that there is a need to tailor this climate information as per the

stakeholder's demand in order to have a productive decision-making process (European Commission, 2015).

2. LITERATURE REVIEW

In this section of the report, the information will be provided about relevant literature, theories, and concepts which support the finding of this paper. It will also help in answering the research question, which will be followed by the conceptual model derived from the theories explained in the following sections.

As discussed in chapter 1 of this research, most of the literature and researchers state that communication factors, information framing, type of information, the visual representation of the climate information must be tailored according to the stakeholder's demand in order to avoid the usability gap between the climate services and the end-users. Among the many theories that could potentially measure the usability gap between the climate services and the end-users, the following theories are most commonly spoken by researchers and are more practical as well as scientific to analyze the factors that influence the usability of the climate services. Hence, this study will focus on these four theories:

1.Communication need model

2.DESTEP model

3.Climate information design

4.Process of adaptation/Decision-making process

The following sections will give a better understanding of the relevant literature for this thesis.

2.1. Defining climate adaptation and its measures

Adaptation can be distinguished based on the time, goal, and motive of its implementation (Knittel, 2016). Anticipatory adaptation is when the action is taken in advance of the impact of climate change, which can be observed (Knittel, 2016). Whereas, reactive adaptation takes place after observing the initial impacts of climate change. In a natural system, adaptation measures are usually reactive in reference to the human system, but of course, it can be both reactive and anticipatory at the same time (Knittel, 2016). Even though adaptation is not a new aspect, it has only come to our attention lately due to the drastic climatic changes. Recently there has been a development in research regarding adaptation strategies and its implementation applications as to how to cope with the impacts of climate change and the socio-economic vulnerability (Ahmed & Long, 2012; *Unfccc.int.*, n.d). Adaptation gives us a direct and indirect model of measures that can be taken in order

to reduce the risks and effects of climate change (Ibid). Adaptation policies and measures will differ from places to regions, their spatial scales, and in various other sectors (Knittel, 2016). Different kinds of climatic changes are seen in Iceland as compared to the climatic variabilities in Africa, for example, the agricultural sector (Knittel, 2016). Since adaptive measures are not one size fits all, and vary across contexts and cases, it is difficult to find an optimal adaptive measure. The policymakers are trying to come up with adaptive policies that are efficient and cost-effective based on specific regions and the challenges of climate change that the region faces (IPCC, 1996; IPCC, 2001; IPCC, 2007; Ahmed & Long, 2012). However, there is still a significant gap related to the policy frameworks as to how to, in what way to, and where to adapt to climate change. Adaptation measures are happening, but it is taking much time to find the optimal adaptive measures for coping with the effects of climate change (Ahmed & Long, 2012).

2.2. Involved actors/ institutions for implementing climate adaptation measures

Most of the adaptation measures are undertaken by both private and public sectors through policies, technologies, investments in infrastructure, and behavioral changes (Knittel, 2016). Adaptation measures usually take place according to each individual's role to act upon reducing climate change impacts and effects (Knittel, 2016). According to IPCC (2007), adaptation strategies should be planned by governmental organizations, private decision-makers, investors, or NGOs or in collaboration with all the actors responsible for adapting towards climate change. Governance also includes a partnership between different stakeholders. Adaptation measures are often guaranteed; however, it also costs much money, time, power, and other such resources for the implementation of adaptive measures (Ahmed & Long, 2012). Any adaptive practice will be useful if we consider the estimated value of circumvented risks and damages regarding the amount of money that was spent on implementing the adaptive measure (Ahmed & Long, 2012). Despite these adaptation measures being so useful, it has been observed that these measures are not always implemented.

2.3. Climate adaptation services and the end-users

Climate adaptation services are tools or services that provide scientific information about climate-related issues for specific regions in order to act upon it and implement adaptive measures (*Stichting CAS*, n.d). According to the project EVOKED, the definition of a climate

service should consist of these following aspects (*EVOKED D1.2-Climate services needs inventory_Final*):

- Provide useful information and knowledge about climate change and its impacts.
- They are used to make climate-informed decisions by the decision-makers and other stakeholders or end-users.
- It acts as a guidance tool or services in order to make use of it and act on it, in terms of climate adaptation measures.
- All climate data is transformed into customized products or services.
- Must consist of a variety of tools, projects, scenarios, and assessments, depending on the target audience and their needs.
- Must support climate change adaptation, mitigation, and disaster risk management.
- It should be user-driven.

Based on the documents in the project EVOKED (*EVOKED D1.2-Climate services needs inventory_Final*), it stated that not a wide variety of climate services are available, even though there is an abundance of climate information/data that is available *(European climate adaptation platform,* n.d*)*. The problem which the end-users face is not just the lack of knowledge but also; (i) knowing which knowledge to use and when, (ii) knowing how to deal with risks and uncertainties related to different kinds of climate knowledge (European Commission, 2015; Vaughan & Dessai, 2014). There are many aspects to how a climate service is designed depending on the goal/purpose, representation, and regional factors. Table 1. shows an example of how climate services can be classified.

SUBJECT	***SUBDIVISION OF SUBJECT***	***NUMBER OF TOOLS***
Challenge	Water management	32
	Disaster risk reduction	21
	Coastal management	26
The goal of the tool	Prepare/inform	41
	Predict	24
	Design to decide	14
	Dialogue	10
Techniques used	Mapping	27

	3D visualization	2
	Tables/ metrics	32
	Photos/visuals	6
At which stage	Plan	48
	Do	20
	Check	14
	Act	7
Scale	National	30
	Regional	24
	Local	29
Used elements of solutions	Participatory planning support tools on decision making	6
	User-centered design of model	16
	Collaborative/ interactive modelling	5
	Visualization	19

Table 1. Overview of the type of existing climate adaptation services/tools in Europe (European climate adaptation platform, n.d)

This table shows the number of existing climate services/tools in Europe, divided into six main subjects and their respective sub-divisions *(European climate adaptation platform. n.d.).* Here it can be seen that most of the climate services are focused either on water management, disaster risk reduction, or coastal management *(European climate adaptation platform. n.d.).* Climate change challenges such as landslides, storm surges, heat stress, etc. are not addressed in these climate services (ibid). Among these services, the majority of the services have a goal to inform and predict climate change, and very few have a goal to initiate dialogue (ibid).

Furthermore, most of the existing climate services/tools represent the information through mapping (27) and tables (32) as compared to 3D-visualisation (2) and photos (6) (ibid). Additionally, most of these services are used in the planning stages rather than the do,

check, and act stages combined *(European climate adaptation platform. n.d.)*. The table also shows a balanced distribution of services at the national, regional, and local scale *(European climate adaptation platform. n.d.)*.

Most of the climate services are designed to support the process of decision making. The table above depicts the different climate services designed to provide information based on different phases of the decision-making process (for example, plan, do, check, and act stages). Some services are designed to better understand the problem and then plan, others for selecting the right measures or for monitoring and implementing the measures. A theory developed by Moser and Ekstrom (2010) on the decision-making process or the process of adaptation includes crucial stages such as understanding the problem, planning different adaptation measures and managing or implementing the measures (Moser & Ekstrom, 2010). Each of these phases has subsections to identify the barriers while adapting to climate change. If barriers occur in any of these subsections, then it will result in problems or unintended consequences later, which will cause issues in implementing adaptation measures due to disrupted decision-making process leading to the usability gap between the climate services and the end-users (Moser & Ekstrom, 2010). There could be some external barriers involved in this process such as governance issues which can be both legal and political factors like political willingness, policies, stakeholders perceptions; lack of time, finance, resources, lack of knowledge and unawareness, lack of skills, behavioral intent, management issues, lack of communication, lack of coordination and collaboration and many more (Moser & Ekstrom, 2010).

Moreover, all these 3 phases are interlinked with one another. The decision making process is slightly less linear and structured in practice than in reality. Thus, many authors feel that this process is more empirical (Moser & Ekstrom, 2010). This theory helps to understand and analyze, at which phase of the decision-making process, the end-users face the difficulty in making informed decisions and implement adaptation measures if there is a potential usability gap between the end-users and the climate services. The gap can be caused due to the information in the climate services not being tailored according to the stakeholder's demands. Thus, improvements can be made in the climate services in order to initiate a successful decision-making process among the end-users. Each of these three phases are explained as follows:

Understanding the problem phase: In this stage, the first step is problem detection and awareness-raising, which results in the initial problem framing (Moser & Ekstrom, 2010). The next step talks about information gathering and using this to understand the problem on a deeper level (Moser & Ekstrom, 2010). Furthermore, the last step is redefining the problem, which results in the framing of information which may or may not need further attention to the issue (Moser & Ekstrom, 2010).

Planning phase: In this stage, the first step is developing options or adaptation measures, which can be potentially implemented (Moser & Ekstrom, 2010). Followed by assessing these options critically and then in selecting the suitable and optimal adaptation measure (Moser & Ekstrom, 2010).

Managing phase: The final stage involves the implementation of the selected adaption measure or option, followed by monitoring the environment and the outcome of the selected option. The last step is to evaluate the measures or options which was implemented (Moser & Ekstrom, 2010). This evaluation can also be done through a feedback loop. Furthermore, this stage is the most critical stage based on an adaptive management approach as it helps in supporting the institutions and enhances social learning, which can also be complex to deal with uncertainty (Moser & Ekstrom, 2010).

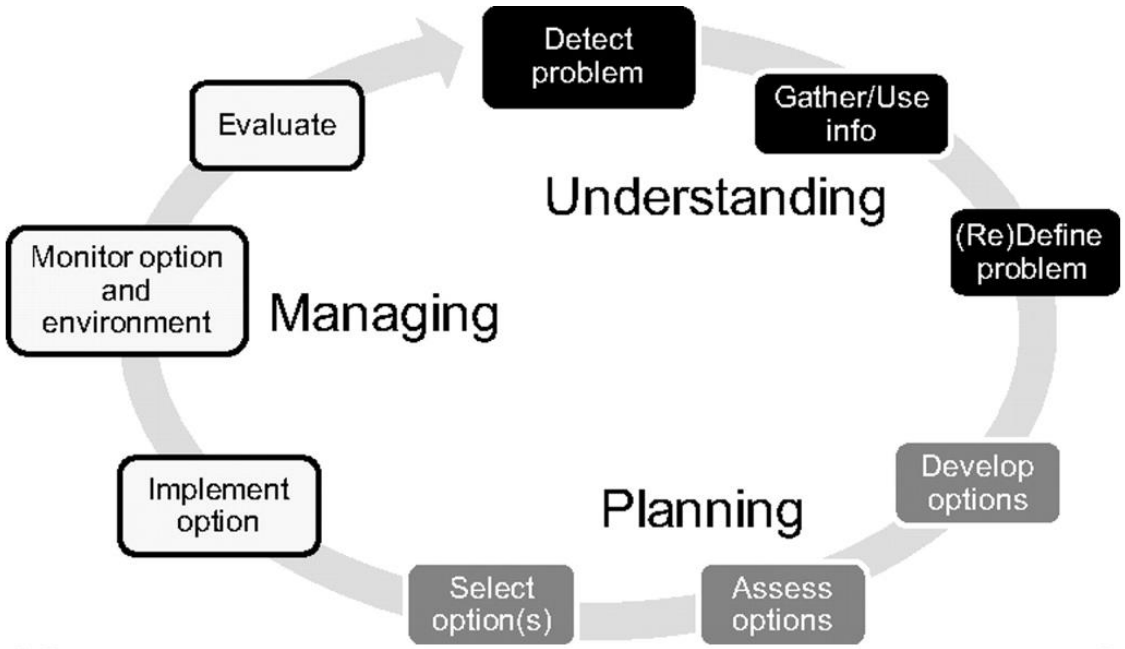

Fig. 2. Process of adaptation/ Decision-making process (Moser & Ekstrom, 2010)

This theory can be adapted to improve climate services so that better and informed decisions are made by relevant stakeholders to implement/monitor climate adaptation measures in vulnerable areas.

According to the EVOKED project documents, climate adaptive services can be tools, projections, scenarios, assessments, or even risk maps that can help or support in the decision-making process, provide expert advice, counseling, and even manage climate adaptation processes (*EVOKED D1.2-Climate services needs inventory_Final*). Climate services are often easily accessible and understandable for the end-users or the responsible stakeholders covering a wide range of audience (national, government, regional government, local government, politicians, construction developer, water boards, Ngo's, Nature protection agencies researchers, citizens and many more) by using a variant of communication and visualization tools (*Stichting CAS*, n.d).

The goal of climate services is to support decision-making and can be directed towards various end-users: politicians, managers, private enterprises, inhabitants, and many more. *"The following is a list of different end-users:*

- *Government: local, regional, and national authorities such as technical staff, administrators, and decision-makers*
- *Business/Industry such as developers, insurance agencies, tourism*
- *Interest groups and NGOs: local, regional, and national (e.g., agriculture, water sectors, and landowner organizations*
- *Citizens to represent the general public such as homeowners*
- *Research Institutes and Initiatives*
- *Politicians: local, regional, and national*
- *Media such as journalists, newspapers, television broadcasts"- (Adapted from EVOKED field trial documents)*

Overall, climate adaptation services can be defined as a service that provides information about climate change, its impacts, or adaptation measures for decision-makers as well as other stakeholders.

2.4. Usability gap between the existing climate adaptation services and the end-users

A recent study was done by Bender and Groth in 2018, at the Climate Service Centre in Germany, "GERICS." The research suggested that it is essential to understand various factors and drivers that influence the adaptation in an urban area and its surroundings, as well as their interactions with one another (Bender & Groth, 2018). Before the planning phase of adaptation and developing adaptation strategies for a city, it is first essential to understand the whole system, such as the knowledge provided by the climate service for the end-users. This knowledge not only includes climatic information but also socio-economic information and land-use trends (Bender & Groth, 2018). According to the researchers, climate services are a very flexible and innovative toolkit, and this has been tested in many cities by municipalities and other government agencies (Bender & Groth, 2018). The main goal of "GERICS" was to promote and support effective adaptation processes and relevant decision-making processes information for the government, administration and other businesses all over Germany, including the densely populated cities as well as cities on the sea (Bender & Groth, 2018). However, even with all the information about the effective adaptation measures, such as using climate-sensitive construction materials, retention of precipitation, reduction of urban heat stress, preservation and expansion of green and water areas, it was observed that there still exists a gap between the theory and the practice of implementing these measures (Bender & Groth, 2018). This gap often occurs due to administrative and economic barriers, as well as the lack of understanding or perception of the end-users (Bender & Groth, 2018).

According to the 5th Assessment report of the International Panel on Climate change (IPCC, 2014), it was stated that there are many economic barriers related to climate adaptation measures during the decision-making process. The adaptation measures are often implemented by both public and private actors. However, the level of desired adaptation measures may reduce due to barriers such as financial limitations, time, resources, power, etc. which occur during the decision-making process (Knittel, 2016). Several barriers exist from an economic point of view that prevents the government from making decisions for adaptation measures such as transaction costs. Due to market failures, many other barriers, such as externalities, information asymmetries, and moral hazards, may also take place (Knittel, 2016).

Behavioral change among the individuals, decision-makers, investors, implementers, and the government to adapt to climate change is the essential aspect to achieve the desired goal of tackling climate change. Lack of positive attitude and motivation among the end-users can lead to a failure in implementing these policies and measures, which are cost-effective and efficient adaptive measures. These failures can also occur if there is a regulatory issue, awareness issue, and an economic problem because of transaction costs. Policies should be made in such a way that it gives clarity and certainty to the investors, implementers, and the other actors involved in acting towards adaptive measures. International support for finance can also be of help. Spreading awareness about climate change impacts and its consequences for each individual to bring a behavioral change is crucial. It is essential for the government to create policies, monitor them, comply with them, persuade the investors and the decision-makers, generate more revenue for adaptive measures and initiate more discussions on how to tackle climate change (Stern, 2007).

Moreover, active participation in planning for climate adaptation requires communicating different types of information to and between diverse stakeholders, including private and public actors (Eliasson, 2000; Sharma et al., 2014). If informed discourse/decisions are to be carried out as well as reduce the amount of uncertainty (if at all), then the end-users need to understand the complex and interdependent systems (Eliasson, 2000; Sharma et al., 2014). Moreover, potential future impacts of climate change and the implications of possible adaptation measures must be shared by participants through the services (Eliasson, 2000; Sharma et al., 2014). Recent research suggests that a lack of awareness and understanding by urban planners about the risks of climate change is a leading barrier to planning for it as well as implementing adaptation measures (Runhaar et al.2012). Political, social, economic, ecological, demographic, and technological issues are also identified as significant barriers in reference to the type of information provided in climate services (Knittel, 2016). Overall, the climate service helps in disclosing information, facilitating shared understanding, and supporting the decision-making process among the end-users.

Furthermore, computer-based tools seem especially advantageous for providing visualization of integrated systems and information, including feedback on the impacts of measures (Eliasson, 2000; Sharma et al., 2014). This is also because research adds new insights to the communication and the use of climate information data by the stakeholders (Eliasson, 2000; Sharma et al., 2014). Different communication formats can play a role in

communicating with different stakeholders, which is essential for the decision-making process for adaptation as it often causes delays in climate adaptation measures (Eliasson, 2000; Sharma et al., 2014). In the literature, there is a significant gap between the qualitative process-based methods that are being used in participatory planning and the detailed models and decision support tools that are still mostly used by experts. In practice, this gap acts as a barrier to the success of carrying out participatory planning in a way that supports decision making and thus, causes a usability gap between the end-users and the climate adaptation services (Fryd et al., 2013; Sellberg et al., 2015; Wardekker et al., 2010). Therefore, research on the choice of format in which the climate information data is presented, understood, perceived, and used by the stakeholders, could serve as a stepping stone to finding solutions to bridge this usability gap. This will initiate the end-users to make informed climate-adaptive decisions. It is also essential to understand and analyze the information provided by the climate services and what other factors influence this usability gap, such as the information format, the intended target audience, etc. (Raaphorst et al., 2017; Raaphorst et al., 2018). There appears to be an opportunity for tools to bridge the usability gap by providing platforms that support participatory processes with scientific content for decision making. To design practical tools, however, a better understanding is needed of the use and effectiveness of tools in supporting participatory planning processes and decision making about climate adaptation.

As observed in Table 1, the majority of climate services/tools are used in the planning phase rather than the managing or action phase of the decision-making process *(European climate adaptation platform*, n.d*)*. Moreover, very few climate adaptation services provide 3D visualization and photos. Instead, they are represented by maps or graphs/ tables, which could potentially influence the usability gap among the end-users in terms of understanding the information and acting upon it *(European climate adaptation platform*, n.d*)*. It was also observed that very few services initiate participatory planning and collaborative/interaction modeling tool to support the decision-making process *(European climate adaptation platform*, n.d*)*.

Despite the fact that there are countless decision support tools available to help local and regional authorities in managing and reducing risks in the face of uncertainty associated with climate change, there is still a large gap between the scientific knowledge produced on climate risks and its usefulness for local and regional policymakers (European Commission,

2009; Barros et al., 2015; Haasnoot et al., 2013; Brugge & Roosjen,2015). According to the European Union, climate services are recognized as an essential part of improving our capacity to manage climate-related risks. Since the climate service sector is relatively new, the EU has identified critical challenges for facilitating the development of this market and enhancing it's quality and relevance (European Commission, 2015; Vaughan & Dessai, 2014).

2.5. Potential factors influencing the usability gap between the climate services and the end-users

Based on the literature mentioned above, there could be many potential factors influencing the usability gap between climate adaptation services and end-users. However, for this research, a few of the relevant and most common theories related to the research questions have been selected to develop the conceptual model. The following are the theoretical frameworks that will be used to answer the research question.

2.5a. Theory 1: Communication needs model

According to many researchers, one of the critical features for the stakeholders to reach a consensus in terms of decision making for implementing any suitable climate adaption strategy is communication (Koers, 2019). To build resilience for climate affected areas, climate information must be communicated by tailoring the information according to the stakeholder's demands (Koers, 2019). Researchers suggest that the best way to communicate and translate information or data is through knowledge-intensive climate adaptation services (Koers, 2019). Based on the insights about climate services from the previous chapter, '*Information about climate change impacts which can help the decision-making process of stakeholders is by raising awareness about climate change impacts, providing insight on the impacts that climate change has on their surroundings as well as offering advice on potential solutions, implementation of measures and evaluating them for handling these impacts, This information can be communicated to stakeholders via different tools, formats and products that they can use to make an informed decision.' (Adapted from* Koers, 2019*;* Hewitt et al.,2012; Vaughan & Dessai, 2014; Bruno Soares et al., 2018, p.6). However, communicating the climate information to stakeholders is often not a simple procedure, as research states that different stakeholder groups can react to and will interpret/ perceive information differently, based on the 'communication formats' or the representation of the information (e.g. reports, story maps, pictures, graphs, maps, etc.) (Berkhout et al., 2014; Raaphorst et al.,

2017; Raaphorst, 2018). Thus, it is essential to tailor the information in the climate services according to the specific target audience and their information needs.

The communication needs model is suitable for this research as it relates to the key four factors (intended goal, intended audience, information framing and the mode of communication) in the communication process that needs to be considered when communicating climate information through climate services to the stakeholders (Moser, 2010). These four points will now be discussed in further detail in their relation to one another, as well as their relation to climate change information data, which is essential in any climate service for reducing the usability gap among end-users.

1. ***What is/are the intended goal(s) of the information?***

   This element is present to inform and educate the end-user. It is also essential to achieve social engagement, active participation, and the feeling of urgency to act for the readers and other stakeholders of climate services. Climate services can have different goals that also link back to different stages with the decision-making process, such as understanding, planning, and implementing. Therefore, the goal of the information does not always have to be about informing or educating or bring changes in social norms and cultural values. It should also be about bringing a sense of urgency to implement adaptation measures effectively and efficiently. This will also help in understanding the effects of climate change as well as the impacts of climate change in an area depending on the demands of the stakeholders. Consequently, this element can be compared to analyze and evaluate the information goal of different climate services and determine the gaps in them.

2. ***Who is the intended audience?***

   Our society is not just one homogeneous mass but, it also consists of different audiences, who have different values and different perspectives towards difficulties that this society faces and can act out of different interests (Benett, 1997). Therefore, Moser (2010) and Lemos et al. (2012) talk about the importance of tailoring the information based on the intended audience or according to the stakeholder's demands, to successfully transfer knowledge and climate information. Hence, for climate information data, it means that the used language (level of technical terms which is easily understood) and the format is necessary as it can potentially affect the

use by end-users, which can potentially result in the so-called 'usability gap' (Lemos et al., 2012 and Weaver et al. 2013). Therefore, this factor will help in understanding who are the target audience for the climate services and the information that should be tailored based on their needs to reduce the usability gap.

3. ***How is the information framed? (e.g., what language, metaphors, and images)***

   The third point made by Moser (2010) is how climate information is framed. Depending on how the information is framed, different users or end-users can perceive and interpret the same information in different ways. Furthermore, the tone, clarity, consistency, information, and advice given should all be helpful, relevant, and applicable to the intended group. The audience may be hostile or ignorant towards expert knowledge (Bucchi, 2008). Personal circumstances can also affect how people process the information, perceive it, and how they can relate to it. This, in turn, will bring a feeling of urgency to take action (Burningham et al., 2008; Martens et al., 2009; Brossard & Lewenstein, 2010; Koers, 2019). All these factors affect the way information needs are to be framed and should be successfully transferred to the stakeholders. Based on this element, the framing of the information of the climate services can be analyzed, and this will potentially result in evaluating the cause of the usability gap among the end-users of the climate services.

4. ***The modes/ channels used to communicate information.***

   The last point raised by Moser (2010) is the influence that the modes/channels of communication have on climate information and knowledge transfer through climate services. He also talks about the way the information is represented to the audience, such as a map, graph, book, report, story map, infographics, 3-D model, etc. The relevance of this way of representation of the information to the stakeholders will also determine the usability gap in the climate services, as the end-users may not be able to read or understand the climate information that is represented by a particular format. Hence, the representation of climate information should always be easily accessible and understandable for all the end-users in order to make decisions to act towards climate change. As explained earlier, climate information can come in a variety of different forms. These different forms have diverse potentials, roles, benefits, and limits (Moser, 2010). However, there can be a distinction made between

written, verbal and non-verbal communication (Moser, 2010). This also determines whether there is an option for two-way communication (dialogue, reflection/ feedback, and learning) or one-way communication. According to Moser (2010), one-way communication is secure for understanding but lacks in educating and changing users. Two-way communication, in that case, is preferable as this will only help in improving climate services.

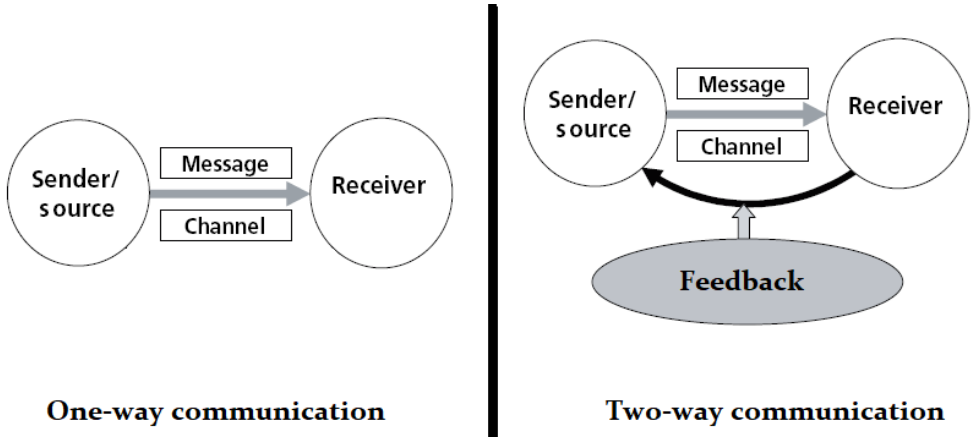

Fig 3. Modes of communication (EWO, 2015)

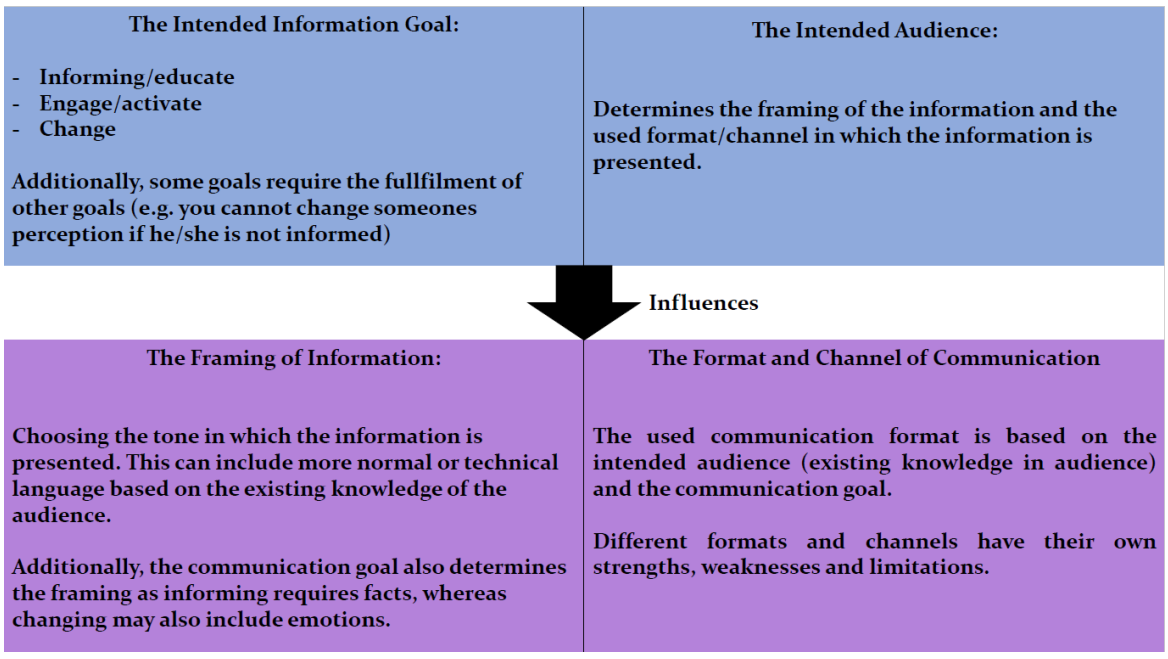

Fig.4. Communication needs for climate services to improve usability (Koers, 2019)

Therefore, by applying this theory of communication needs model for climate services, the expert's opinion on the existing climate services in each case study area can be compared and analyzed, which will contribute to determining the various potential factors influencing

the usability gap. Such as the relevant stakeholders or the target audiences of the climate services, the mode of communication, the way the information is framed, and the goal of the climate service. These factors can be evaluated based on the stakeholder's demands and if the information is accessible and understandable for the end-users in order to explore the potential usability gap and further reduce it.

2.5b. Theory 2: The DESTEP Model for strategic planning and decision making

The DESTEP model consists of 6 elements from the macro-environment, such as Demographic factors, Economic factors, Social, Technological, Ecological, and Political/legal factors (Vlieger, 2012). This model has been selected as the type of information provided in the climate services for the end-users also plays an essential role in making informed decisions and then act upon it. All these factors provide a holistic overview of the specific region based on which the end-users can plan and act upon implementing suitable adaptation measures by understanding these six elements through climate adaptation services. Using this analysis, any organization can derive strategic benefits from this. Francis Aguilar, a Harvard professor, first created the PEST analysis model (Political, Economic, Social, and technological factors) as a strategic tool in his book about lines of communication and analysis in 1967 (Frue, 2017). Later, the Demographic and the ecological factors were also included for strategic planning, smarter decision making, and analysis process in the macro-environment. The figure below depicts the six elements based on the type of information needed in climate services for the end-users to make informed decisions for strategic planning and implementation of adaptation measures.

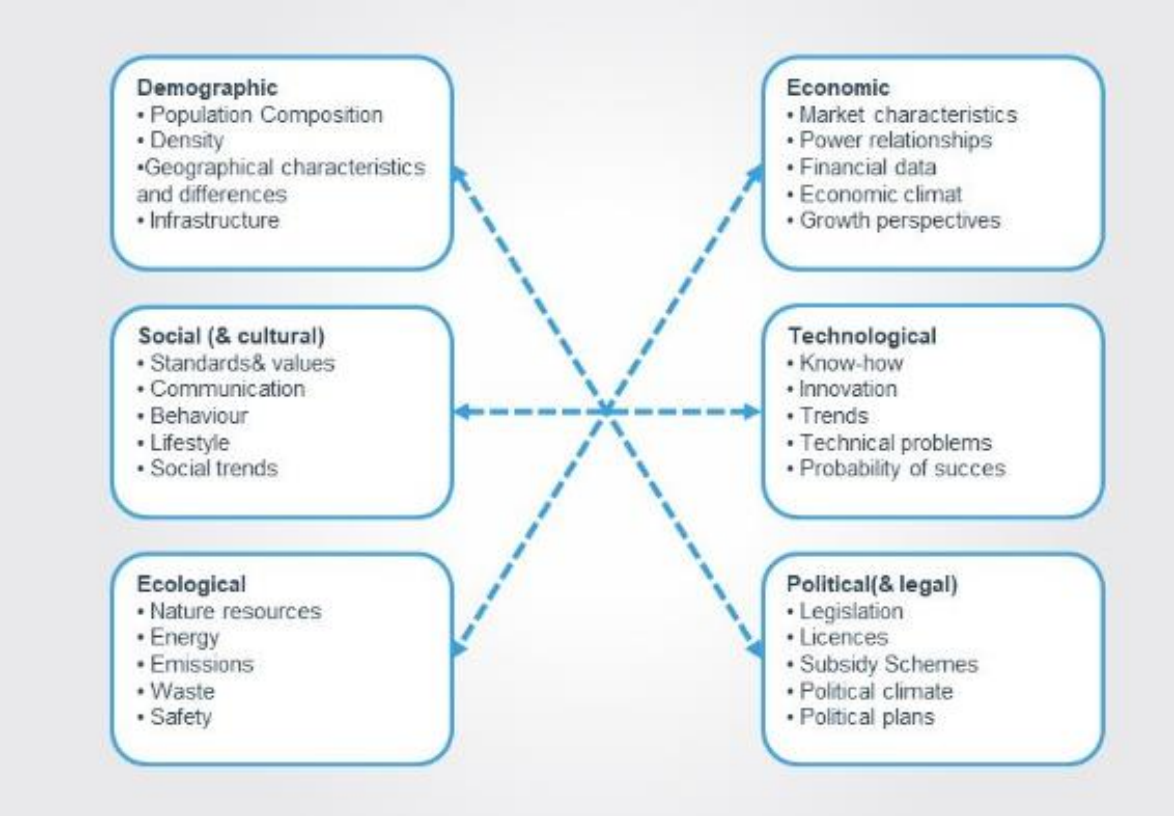

Fig. 5. DESTEP analysis model for strategic planning and decision making (Vliet, 2010)

The following are the DESTEP factors or the type of information necessary in the climate services, for the end-users to make informed decisions:

- ***Demographical factors***

  This factor influences the process of decision making, as an increase or decrease in the inhabitants of an urban area will affect the resilience towards climate change (Koers, 2019). This will also bring a change in the spatial planning developments, housing, and businesses, which will, in turn, affect the economy of the country as there will be less employment and an increase in financial pressure in terms of high taxes but low wages (Koers, 2019). The performance of the adaptation measures and its development will also decrease due to less planning and management (Koers, 2019). Thus, this factor also plays a vital role in the strategic planning and decision-making process for implementing adaptation measures, which will potentially reduce the usability gap between the end-users/ decision-makers and climate services.

- ***Economic factors***

  The economic aspect and the political role are almost interlinked with one another. Since, the economic growth and the profit often overrules other influences in the decision-making process, which then leads to decisions not being in favor of implementing adaptive climate measures (Koers, 2019). In this aspect, the monetary cost damages can also be observed by the government stakeholders, which will benefit in prioritizing the adaptation measures and implementing them (Koers, 2019). Information on the economic aspect will, in turn, help the end-users to make informed decisions.

- ***Social factors***

  In terms of the effects of climate change, many cities in this world have faced droughts, floods, cyclones, heat stress, etc. It has been observed that potential climate adaptation barriers are present at every level of the government, which hampers the implementation of climate adaptation measures (Runhaar et al., 2012; Biesbroek, 2014). The usability gap also increases due to lack of experience, skills, unawareness, and having a low-risk perception of these types of climate change impacts among the end-users/ decision-makers of the climate services. This consequentially interferes with the political aspects, the decision- making process, and the implementation of adaptation measures (Koers, 2019; Orr et al., 2015).

- ***Technological factors***

  Due to a lack of accuracy in predicting and modeling the climate impacts, there is uncertainty in the decision making, thus, questioning the decisions that were based on modeling results (Moser & Ekstrom, 2010; Koers, 2019). This, in turn, influences the usability gap between climate services and the end-users. Technological factors play a small role in the decision-making process. However, this is mainly due to the lack of accurate technology and the information which can be easily accessible for planners to initiate a spatial planning process (Eliasson 2000; Koers, 2019). Even though there are constant technological developments in the world, it also can be linked to the political aspect through policy documentation for climate change adaptation (Koers, 2019).

- ***Environmental/ ecological factors***

  These factors play an important role in the planning phase as they influence spatial planning interventions and measures which need to be fitted in the already existing physical environment. This has a logical standpoint, among other factors in the physical and spatial features (Immink, 2005; Wiering, 2006; Koers, 2019). Therefore, environmental/ ecological factors are useful in planning, managing, and informing phases (Koers, 2019).

- ***Political/ Legal factors***

  Political and legal factors play the most crucial role in the decision-making process for implementing climate adaptation measures (WDOD, 2018; Koers, 2019). For example, if a climate-adaptive spatial design is implemented in a vulnerable area and due to that design, the effect of climate impact is more, then it would overrule the decision-making process as the government stakeholders must legally act on it to prevent further damage. Furthermore, the stakeholders who implemented the design would be legally responsible for the damage or the wrong decision (WDOD, 2018; Koers, 2019). As such, the decisions can be overruled; however, it will only occur if there is a post-anti-reaction to the climate change impact (WDOD, 2018; Koers, 2019). Politics has a more significant influence in the decision-making process, especially in a negative sense because political agendas influence the spatial planning process of the municipalities (Biesbroek et al. 2011; Runhaar et al. 2012). Political willingness is a critical factor that enables climate change measures, and if this improves, then it will be easy to bridge the usability gap of climate services for its end- users. This can be achieved by understanding the information needs of the audience based on their demands and thus focus on their political willingness to act by showing the local effects and impacts of climate change through images, maps, videos etc. (Biesbroek et al. 2011; Runhaar et al. 2012; Koers, 2019). This will result in identifying the barriers and overcoming them.

Therefore, all these factors in the DESTEP model influence the decision-making and planning process. As these occur on different scales and are interconnected to one another, it may also affect other factors such as governance issues, monitoring and implementing climate adaption measures, and collaboration with other stakeholders. All these factors

mentioned in the DESTEP model are essential information needs of the stakeholders in order to make informed decisions for climate adaptation measures. If the type of information - DESTEP factor is not tailored according to the stakeholder's demands in the climate services, then the usability gap rises. The DESTEP information factors also help in adapting to a socio-economic climate-proof resilience development in an urban system as the influencing factors will be determined and evaluated to improve the usability gap of the climate services among the end-users. Such information present in the climate services with all the influencing factors will lead to reducing the usability gap of the climate services among the stakeholders as these are few of the information needs which will initiate them to make decisions based on planning and adapting to climate change. Factors like political awareness, economic costs, and other environmental factors, etc. contribute to decision making at every stage. Eliasson (2000) also concluded that knowledge about climate change, its impacts and effects have a lower impact on the planning process in general, however limited budget, lack of knowledge, political willingness and other such priorities play an essential role in the planning process for the end-users of the climate services.

2.5c. Theory 3: Climate Information design- Factors influencing the usability gap

The climate information design framework was developed by the project partners of EVOKED based on Kevin Raaphorst's conceptual model of visual communication, which was a part of his Ph.D. in Landscape architecture. Kevin Raaphorst based this theory on Steven Sheppard's journal on "Landscape visualization and climate change: the potential for influencing perceptions and behavior" (Sheppard, 2005). According to Sheppard in 2005, landscape visualization with its emerging techniques shows a considerable improvement in communicating some of the climate change issues, enhancing social learning, influencing the viewer's perception and behavior on climate change based on different visual aids (Sheppard, 2005). Evidence and research suggest that the effectiveness of visualization as a planning tool can enhance cognition and behavioral impacts, but less research is done on the realistic landscape visualization (Sheppard, 2005). However, experience suggests that landscape visualization has an enormous effect on the policy through visual media that enhances the behavioral effects by engaging emotional responses (Sheppard, 2005). This technique gives possibilities for engaging in planning activities, awareness building, enhancing motivation,

and feeling of urgency to act towards climate change. However, it also has a few challenges like ethical issues, bias, disclosure, drama, and defensibilities (Sheppard, 2005).

According to Raaphorst et al., (2016), visual representation is the key to communicate with the stakeholders in a design process. Through this theory, the concept of visual and critical social theory, such as visual semiotics, simulacra, and simulation and the power of knowledge or information about climate change, can be critically evaluated and reflected upon (Raaphorst et al., 2016). This helps in representing each stage/ category through visual methodologies to analyze the influencing factors and barriers such as the dominant power structure, miscommunication between participants, optical path dependencies during the landscape design process (Raaphorst et al., 2016).

The goal of this theory is to evaluate the climate services based on five significant factors that could influence the usability gap, such as the stakeholder/ target audience, information purpose/goal, spatial/ temporal measures or actions, type of information, and the type of visual representation. This framework is also based on the previous theory of Moser (2010) about the communication needs model, incorporating the intended audience and intended goal. Information framing, as well as model or channel of communication, is not incorporated in this theory of climate information design. This design has also incorporated the type of information, such as the DESTEP analysis model by Francis Aguilar. Each of these factors can be expanded and be overridden by other factors such as in the information category; the DESTEP factors can be applied instead of only political, social, economic, and ecological/ physical factors. Additionally, the climate information design also consists of other factors such as the spatial/temporal aspects and the type of visual representation. All of these factors will be explained further in order to understand and operationalize the theory, which will help in determining the potential factors influencing the usability gap between climate services and the end-users. The climate information design framework gives a practical and theoretical base for analyzing climate services and understanding the gaps. To improve or minimize the usability gap, this theory plays the most crucial role as it includes all the components that may influence the usability of a climate service from the perspective of its information design.

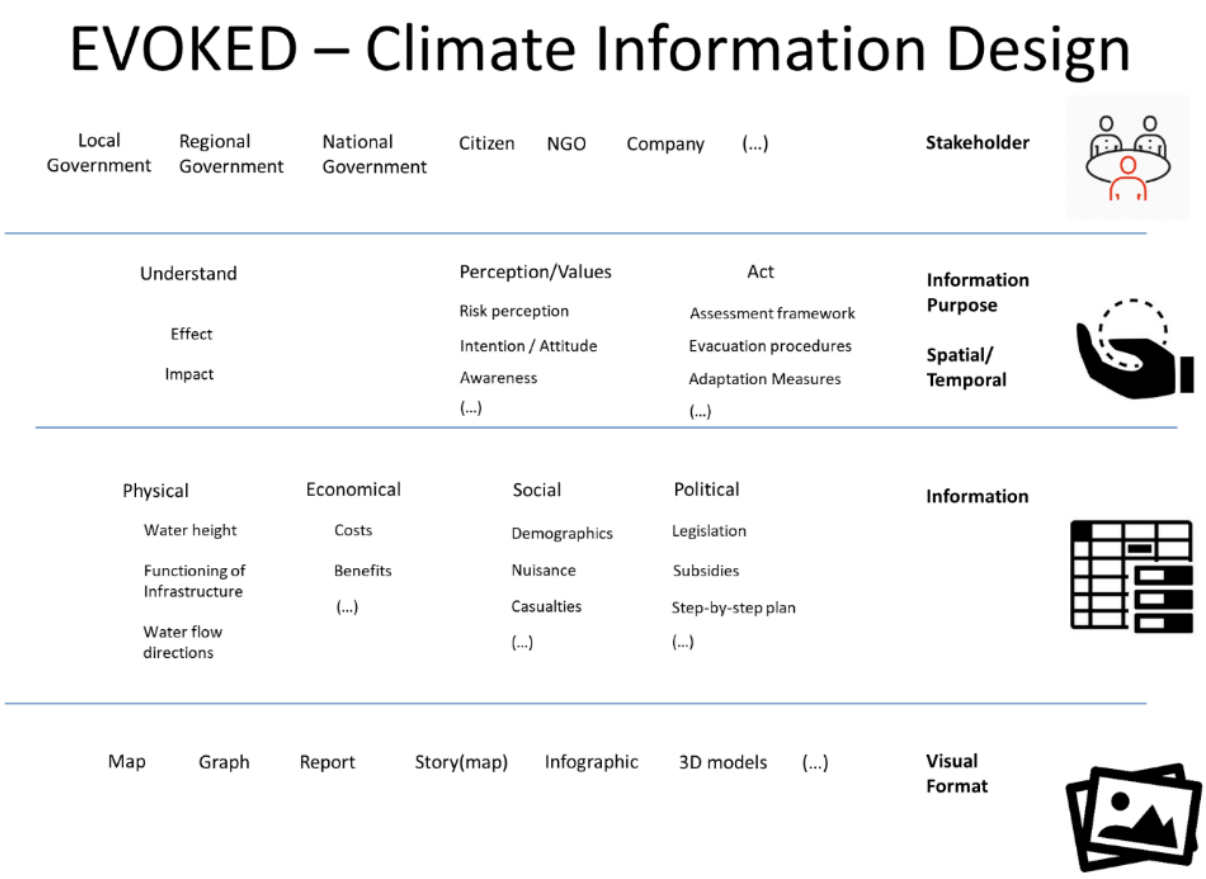

Fig 6. Climate Information design (Raaphorst, EVOKED, n.d)

This framework will be used to determine the factors that potentially influence the usability of climate service among the end-users. There are five significant factors in this framework, which will be explained as followed:

STAKEHOLDERS/ TARGET AUDIENCE:

Based on this category, the climate services can be analyzed in terms of which end-users or stakeholders can use this tool and if these climate services are useful for them to obtain information to make decisions to implement the adaptive climate strategies. For example, if a climate service is helpful for stakeholders such as the Local, Regional, or National Government, NGOs, Citizens, and companies/ Investors. This category will help in understanding the involved stakeholders and their role in using these climate services. Furthermore, the analysis will also assist in understanding why or why not these climate services are not being used by the stakeholders and what could be done to reduce the usability gap.

INFORMATION PURPOSE/ GOAL:

This category will determine the goal of the information available in the climate services and how relevant it is to the end-users, for example, if the data is about climate effects or climate impacts. Further, it will help in identifying the needs of the end-users. The stakeholder's perception or values also play a role in analyzing the usability gap of climate services. For example, if the data provided in the climate service increases the stakeholder's awareness about climate change or the feeling of urgency, change their risk perception or their attitude/intention towards building a resilient city. Therefore, analyzing this category will again help in understanding the information needs of the end-users and the gaps in the climate services, which leads to the underutilization of these services.

SPATIAL/ TEMPORAL:

This factor delivers information about what kind of action does the climate service provide to the stakeholders in terms of space, and if they do so, then how useful and practical are they to be implemented. For example, a risk assessment framework, evacuation procedures, adaptation measures or mitigation measures, etc. This factor is essentially action-oriented. Hence, this information can also play a big role in making decisions by the stakeholders to implement strategies, and it all depends on how essential or relevant is this information to all the stakeholders, which also determines the usability of the climate services.

INFORMATION:

This is one of the most crucial factors that can influence the usability gap of climate services among the end-users. It all depends on what kind of information is provided by the climate services to the end-users. This factor is similar to the DESTEP model discussed in the previous theory, which is the type of information. For example, it mentions the physical social, economic, or political damages or risks that can happen due to the impacts of climate change in an area or a city. However, in this model of climate information design, this factor also relates to how this information is framed in the climate service. The information factor is also essential for the stakeholders to relate to and make decisions accordingly.

VISUAL REPRESENTATION:

The last category determines how the climate services represent their data for the end-users and if it has a positive effect on them regarding understanding the information provided and

then acting. For example, the information in the service or tool can be represented by a map, story map, graph, pictures, text, infographics, report, 3-D models, etc.

Based on this analysis of the climate services the results can be drawn as to why there is a usability gap, what are the information needs, how can the information be tailored to the end-users and what measures could be taken to minimize it? Thus, a combination of these literature and theories mentioned above will help in answering all the research sub-questions based in this research,

2.6. Deriving the factors influencing the usability of climate services and developing a suitable conceptual model for this research

In this section, based on the theories related to the usability of climate services, it was possible to derive the potential factors influencing the usability gap between climate services and the end-users.

- **FACTOR 1 (F1)-** *Addressing the right* ***target audience/ end-users*** *for climate service.*
- **FACTOR 2 (F2)-** ***Relevant information goal/purpose*** *of the climate service (e.g., effects or impacts of climate change, risk perception, increase awareness and active participation), as well as the* ***information framing*** *(e.g., technical information, language, user-friendly, etc.) of the climate service.*
- **FACTOR 3 (H3)-** ***The type of relevant information*** *such as demographic information, social, economic, technological, ecological, and political information based on the stakeholder's demands.*
- **FACTOR 4 (H4)-** *The type of* ***communication channel*** *for the stakeholders (for example, using one-way communication instead of two-way communication).*
- **FACTOR 5 (H5)-** *Relevant* ***spatial /temporal knowledge (action-oriented knowledge)*** *(e.g., Information of risk assessment framework, evacuation procedures, or adaptation measures) provided in the climate services.*
- **FACTOR 6 (H6)-** *Appropriate* ***visual representation*** *of the climate information in the services (e.g., graphs, maps, tables, 3D-models, infographics, reports, etc.).*

Thus, based on all the derived factored mentioned above, a conceptual framework was developed to conduct this research. The following figure 7 depicts the essential factors that could potentially influence the usability of a climate service.

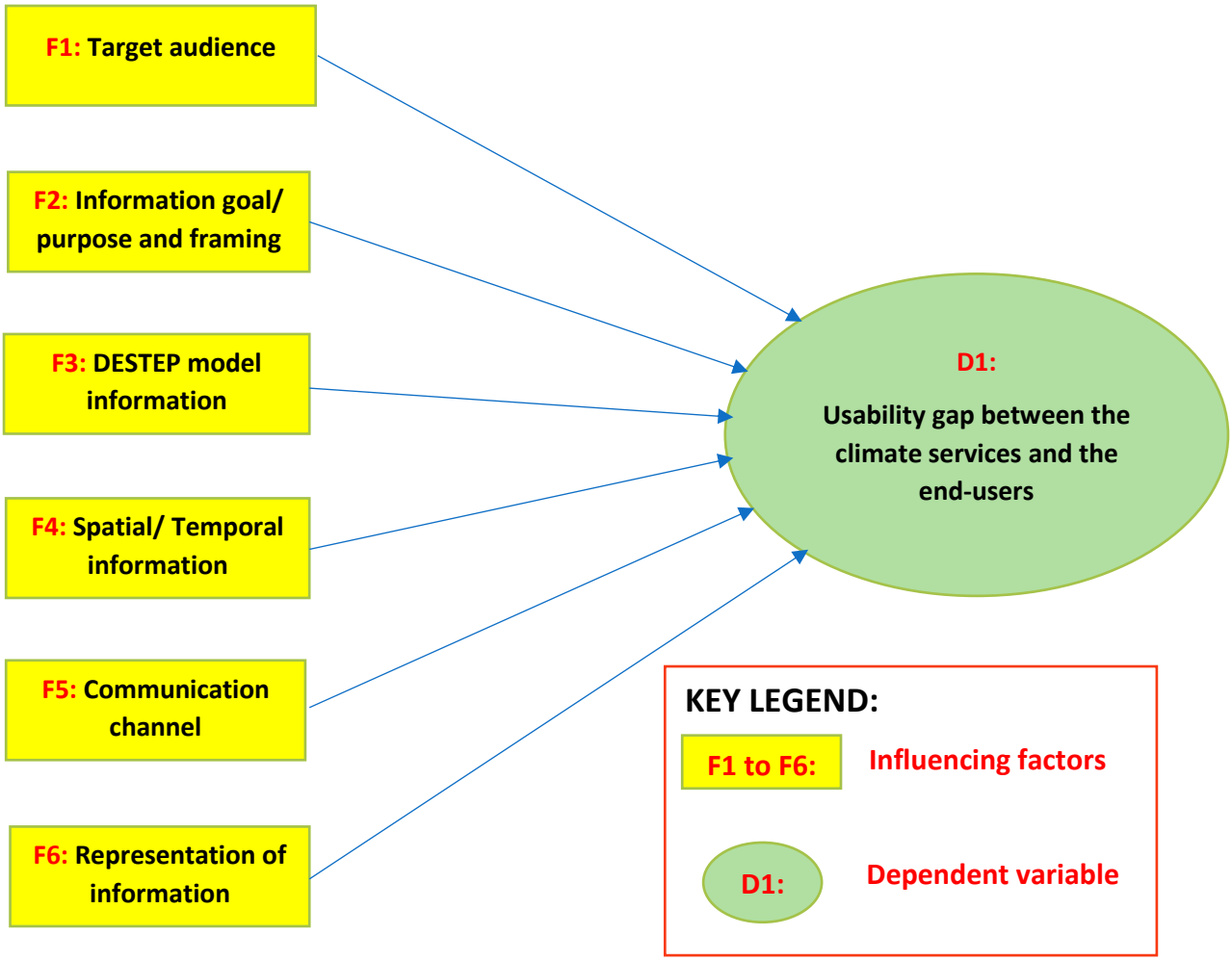

Fig 7. Conceptual framework (Influencing factors that could potentially influence the usability gap between the climate services and the end-users, Edited by the author)

2.7. Conclusion of the literature review

To conclude this chapter of the literature review and theoretical frameworks, it can be stated that there can be many possible explanations for the usability gap of the climate services among the end-users. It could be caused due to lack of understanding the information provided in the climate services, wrong perception of the information provided, lack of relevant type of information, lack of purpose or the goal, the target audiences, lack of information needs based on the stakeholders demands, lack of information framing, lack of visual representation, lack of non-climatic information on the climate services such as

political, social, ecological, economic etc. In addition to these factors, there could also be a lack of communicating the information or the channel used to communicate with the end-users through climate services, lack of motivation or the feeling of urgency among the stakeholders, lack of information supporting administration, governance and other businesses during the understanding, planning and implementing phases of the adaptation process or decision-making process are few external factors. This thesis will mainly focus on understanding the usability gap between climate services and the end-users based on the factors mentioned in the conceptual model, which are as follows:

- Target audience
- Goal/ purpose of the climate service and the information framing
- DESTEP model- type of information
- Spatial/ Temporal information- action-oriented information
- Communication channel
- Representation of the information

3. RESEARCH DESIGN

3.1. Introduction to the research strategy:

This section of the thesis outlines the information on the research strategy, methods of data collection, and data analysis that were used to conduct this research. Furthermore, it provides information on how the research questions will be answered, including the justification as to why selected methods of analysis are appropriate for this research.

Research strategy:

To conduct this research, a case study strategy was used because it offers a detailed and extensive analysis of a geographical location (Bryman, 2008) within a real-life context to gain a better understanding of a phenomenon (Yin, 2013). A case study strategy combined with qualitative research gives an in-depth holistic approach to the investigation (Tellis, 1997). Additionally, Yin (2013) also states that using multiple cases for a case study is considered to make the study more robust and compelling. This multiple case study strategy is designed from a participant's point of view, where different sources of data are used, such as interviews, documents, literature reviews, surveys, archival records, etc. A case study strategy is also known as a triangulated research strategy as this triangulation can also occur with the data, theories, methodologies, and investigators (Tellis, 1997). Triangulation can be defined as a valid procedure where the researcher collaborated multiple sources of data collection, different sources of information in order to form themes and categories for the study (Creswell & Miller, 2000, p. 126; Golafshani, 2003). This need for triangulation arises due to the ethical need in order to confirm the validity and reliability of the process (Tellis, 1997). Thus, multiple sources for data must be collected (Tellis, 1997), which was also done in this research and will be explained further in the next section of research methods. This research is a cross- comparative case study as a group of cases were studied to compare the factors influencing the usability gap in different climate services, their focus, the climate impacts, different target audiences for the climate services, etc. Therefore, a multiple exploratory case study strategy was used for analyzing the usability gap in all the case study sites depending on the climate impacts in those regions, climate services, and the expert's opinion in that region.

Within the scientific research methodology, there are two types of traditional research paradigms, such as quantitative research and qualitative research (Newman & Ridenour, 1998). Therefore, to select the right research approach, it is essential to understand the purpose and the goal of the research. If the goal is about understanding the underlying reasons, motivations, and beliefs or why something is happening, then a qualitative approach is more suitable. Additionally, if the research purpose is to measure and correlate the data after finding them from several respondents, then the quantitative approach is more applicable in this case (Hennink et al., 2011).

Therefore, based on the main research question as previously discussed, we can conclude that the most appropriate research methodology is the qualitative research approach, which consists of analyzing existing documents, workshops, literature, interviews, and surveys. The main objective of this research is to understand the factors which influence the potential usability gap between climate services and end-users. The analysis of these factors is based on the stakeholders and project partners' perspective and how this information can reduce this gap in order to improve the decision-making process. This will also help in explaining the gap and identifying each of the influencing factors based on the conceptual model and the framed factors in the previous chapter.

The strategic map represented below depicts the research strategy for this thesis.

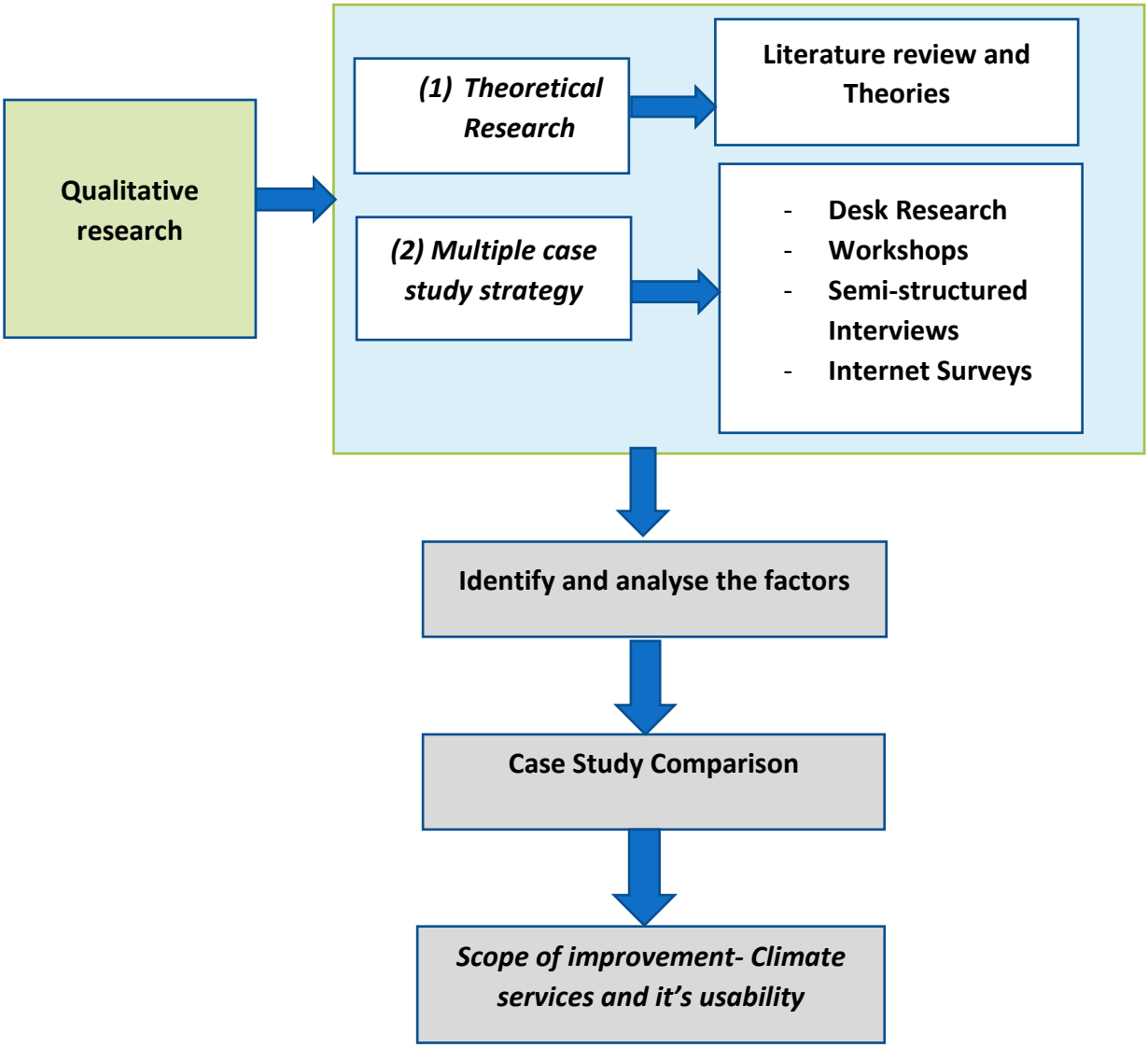

Fig 8. Strategic map for this research

3.2. Case study selection

In this section, a brief introduction will be provided about the case study sites, their location, and the climate change impacts that they are facing. Furthermore, this section will also justify why these areas were selected for this research.

As mentioned in the previous section, I decided to conduct this research through a multiple case study strategy to explore the usability of climate services in various regions. My criteria for selecting the case study sites was to explore the usability gap of the climate services in European countries. Thus, I began evaluating countries in Europe that could be potentially suitable for this thesis. The first criterion was to explore countries that use climate services to make informed decisions. The second criterion was to choose countries that face

similar climate impacts in their region. Moreover, the last criterion was to select study sites that have similar decision-making characteristics, governance, democracy, and economic development as compared to The Netherlands. Thus, I selected 5 case study sites based on these criterions.

Case study site 1: City of Larvik in Norway

Case study site 2: Värmland (Arvika) in Sweden

Case study site 3: City of Flensburg in Germany

Case study site 4: North-east Brabant in The Netherlands

Case study site 5: Drenthe Overijssel (Fluvius region) in The Netherlands

The map below *(figure 10)* depicts the area of the case study sites for this research. The geographical location of the city of Larvik in Norway and the city of Flensburg in Germany and three other regional case study sites, which include Värmland (Arvika) in Sweden, North-east Brabant and Drenthe Overijssel in The Netherlands.

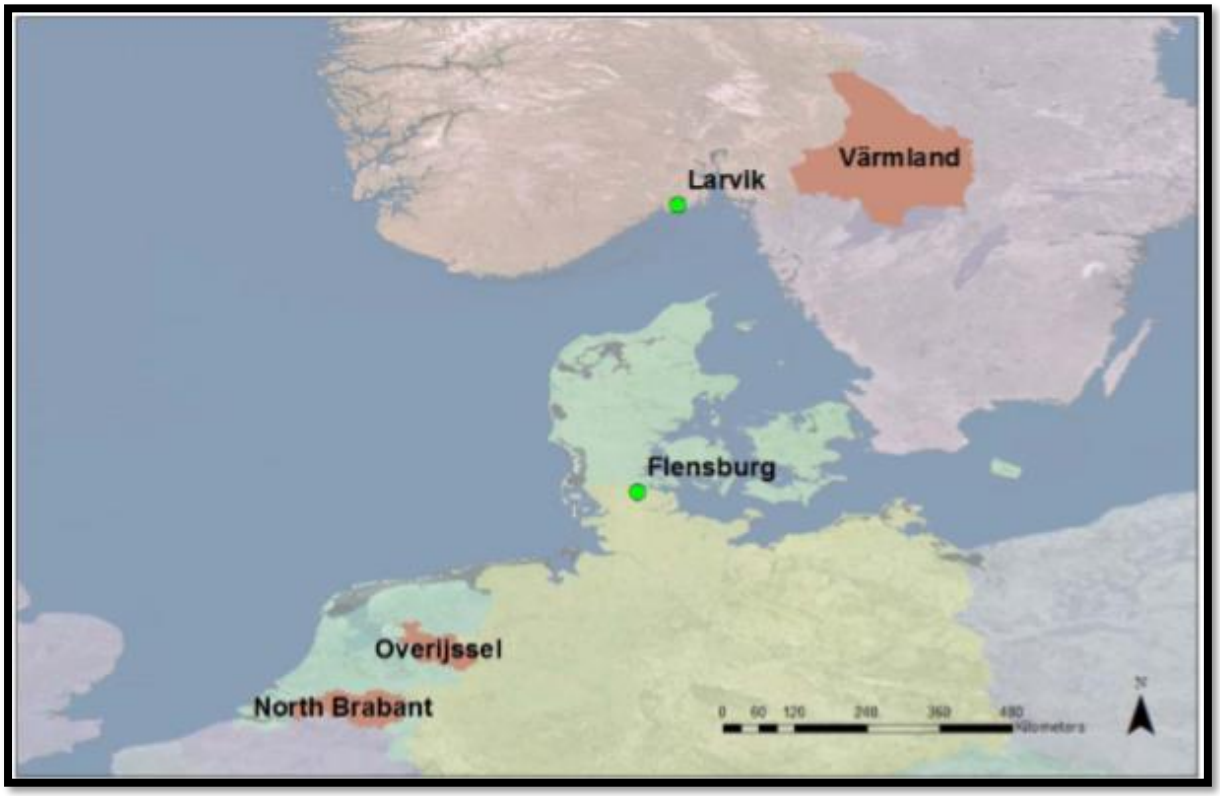

Fig. 9. Geographical locations of the case study sites (NGI. EVOKED, n.d.)

The reason for selecting these 5 case study areas is that all of these countries are situated in the Northern and Western Europe region and are a part of the European Union. Therefore, these four countries have a democratic government, similar decision-making systems, governing policies, high economic development levels, and more bureaucracy among the stakeholders involved in making informed decisions (*Country Comparision-Indexmundi,* n.d). Since all the case study sites are located in Northern Europe, they face similar climate change impacts and risks such as pluvial and fluvial flooding, rise in sea level, extreme precipitation, droughts, storm surges, landslides, heat stress and many more. However, there is a different focus on the climate impacts in each case study area, which leads to a different focus on the climate services for that region. This aspect made it more substantive for me to select, compare, and analyze the case study areas in-depth to understand the climate services and its usability. All the selected case study regions primarily focus on urban areas, except the Fluvius region-Drenthe and North-east Brabant in The Netherlands, which focuses on both urban and rural areas. Thus, comparing the study areas on different scales will make this research more practical. As these case study sites have different climate impacts due to different climatic zones, they will also have various climate adaptation measures with respect to different target audiences, different adaptation issues, and diverse spatial planning cultures for each of these cases. Due to all of these similarities and differences between these case study sites in Europe, comparing these cases and finding the common factors which influence the usability gap between the climate services and the end-users made me more interested in conducting this research.

From the practical point of view, choosing these case study sites was also crucial as I was a part of the EVOKED project, which included all of these case study areas. Being a part of this project, I was able to access and gather all the information from different project partners, such as the researchers and stakeholders involved in this field of study from all these four countries, despite the language barrier. Thus, selecting these 5 cases to conduct a cross-comparison study for this research was motivating and exciting for me.

3.3. Research methods and data collection:

The purpose of this section is to provide an outline of the research methods which are used in this study. It also describes and justifies the research methods used, the proposed

data collection method along with procedures and tools used for the analysis in order to conclude this research.

This study consisted of desk research and primary research in order to collect and analyze primary and secondary data. Desk research is also commonly known as secondary research, where the researcher reviews other people's previous research findings to gain a broad understanding of the same field instead of collecting the data (Travis, 2016). A secondary research/ desk research approach was applied in this research to review the previous relevant literature, theories, and the existing research documents of the project EVOKED in order to explore and analyze the factors influencing the usability of a climate service.

Furthermore, primary research was conducted based on secondary research (relevant theories, literature review, and existing documents of project EVOKED) by conducting interviews and surveys for each case study site. To gather more data about each case study site, I also attended workshops with the EVOKED project partners (researchers and practitioners) from each case study site. During this workshop, the project partners discussed a brief overview of the case study area, climate impacts, existing climate services, focus of the climate services, the relevant stakeholders, and the representation of the climate services. By gathering all the necessary information from the project partners, a case -comparison study was more natural to conduct. Additionally, a series of Skype interviews and closed-ended internet surveys were conducted with the project partners, stakeholders, and the working groups of the project EVOKED to assure their validity. To gain a deeper understanding of the usability gap and the factors influencing it, the stakeholders/end-users and the project partners' perspective was the most important data that had to be collected. Therefore, first, a series of interviews were conducted with one project partner and one stakeholder from respective study sites, and in order to verify the data collected from the interviews, internet survey questionnaires were sent out to the remaining project partners, working groups, and stakeholders who were involved in this project.

As mentioned in the previous section, regarding research strategy, in Phase 1 (Theoretical research), relevant literature and theories were interpreted and were further applied in the next phase. In Phase 2, multiple exploratory case study strategy was conducted, which consisted of 4 European countries comparison of the case study sites based on climate

change impacts and their existing climate services based on the factors that influence the usability among the end-users. This analysis validated the data collected from the literature review and theories and, thus, helped in determining the influencing factors that could potentially cause the usability gap between the climate services and the end-users. A mixed-method of desk research/ secondary research and primary research was conducted in phase 2 of this study to collect data from the end-users and project partners of EVOKED. This ensured the reliability and validity of this study. The mixed-method approach helped in gaining a clear perspective of the topic as well as assisted in forming the semi-structured interview guideline and the internet survey questionnaires for the participants.

A case study comparison was made to analyze the factors influencing the usability gap between climate services and the end-users, which was based on expert opinions. Furthermore, this framework will also allow other scientists and researchers to follow the same methodology to develop climate services that are useful to the end-users to implement climate adaptation strategies worldwide. The last step was to formulate the scope for improvements in these climate services and generate recommendations that can be applied to climate services. This data can be useful in the future to minimize the usability gap among the end-users so that they can participate actively in implementing the adaptive climate measures for climate-vulnerable areas.

Data collection:

***Desk research*-** Relevant literature, research documents, existing surveys, and records of the EVOKED project were used to gather information. Documents that were available from all the case study sites for the project EVOKED were analyzed. The key informants that were selected to conduct the semi-structured interviews from each case were also requested to send in documents, templates of climate adaptation services that were being newly developed, as well as any further information which could be beneficial for this research or that were relevant to their daily work. A few of the informants responded to this request as it was sent via email after the interviews had taken place. By conducting desk research, most of the existing documents of the project EVOKED were coded and analyzed in Atlas.ti software, to find the potential usability gap between the climate services and the end-user in each of the case study areas. A list of 24 documents can be found in appendix 5; however, the EVOKED

documents are only for internal use, and due to the confidentiality clause, these documents cannot be cited.

Skype Interviews- A semi-structured interview was carried out with the relevant participants from each case study site. The choice for using a semi-structured interview method versus structured and unstructured interviews was because on the one hand it provides an in-depth knowledge of information that covers specific essential topics during the interview (e.g. perspective of climate services, use of climate services, view on the usability gap, potential factors causing the usability gap or affecting the decision making process), while on the other hand it also leaves room for potential different additional data, ideas or reason that come up during the course of the interview (O'Leary, 2014). Therefore, to conduct Skype interviews, a set of semi-structured questionnaire was designed. The goal of the interview was to understand their in-depth perspective of the climate adaptation services and its potential usability gap among the end-users, as well as the factors that could be influencing this gap. This interview gave a broad perspective on ways to reduce the usability gap when compared to each case study site.

Before conducting the interviews, an interview guide was developed, which served as a guideline during the interview, and this was also necessary for a semi-structured or structured interview (Hennink et al., 2011). The interview guide firstly consisted of an introduction with the goal of the interview and the research, as well as information about the ethical issues such as audio recording the interview for transcribing, duration of the interview as well as guarantee anonymity for the respondents. This helped the participants to understand the objective of the interview. Secondly, it also contained opening questions that cover broader topics related to the research topic (e.g., questions about background and the relevance of the respondent's work to the research topic); thirdly, focused key questions were designed to collect data and information that could be used to answer the research questions; and lastly, the closing questions were again broader like the opening questions. This increasing and then decreasing focus during the interview is based on the idea of building rapport (Hennink et al., 2011). The interview guide can be found in appendix 1.

The participants were selected by doing a purposive sampling, as the interviews needed to be in-depth and relevant to each case of the EVOKED project. Purposive sampling is commonly used in qualitative research when the information collected needs to be

productive and related to the case of the researcher as well as their interest (Palinkas et al., 2015). This type of sampling also plays an important role in the implementation studies (Palinkas et al., 2015).

There was a total of 5 Skype interviews with 9 participants, which included one researcher and one practitioner/ stakeholder from each case study site, expect for North-east Brabant in The Netherlands, where only one practitioner was interviewed as the researcher was not available for this case. However, since there was an additional case study site in The Netherlands (Drenthe), the required information was gathered from the researcher of the Drenthe case study site. The list of case study sites and the number of respondents from each organization are as follows:

- North-east Brabant, The Netherlands (1 participant- 1 Stakeholder/Practitioner from the Province of North Brabant)

- Drenthe, The Netherlands (2 participants- 1 Researcher from Deltares and 1 Stakeholder Practitioner from the Regional Water Board of The Netherlands)

- Larvik, Norway (2 participants- 1 Researcher from Norwegian Geotechnical Institute [NGI] and 1 Stakeholder/Practitioner from the Larvik Municipality)

- Arvika, Sweden (2 participants- 1 Researcher from Swedish Geotechnical Institute [SGI] and 1 Stakeholder/Practitioner from the Värmland County Administrative Board)

- Flensburg, Germany (2 participants- 1 Researcher from Christian-Albrechts University Kiel and 1 Stakeholder/Practitioner from the Municipality - City of Flensburg)

Furthermore, all the interviews were audio-recorded in order to transcribe them in a word document and then analyze them by using Atlas.ti software by applying codes. This will be further explained in detail in the data analysis section below. Here it can again be observed why the application of mixed methods approach is necessary, as there is a limited number of interviewees from each case. Thus, to get an overview and verify the results obtained from these interviews, it was essential to conduct an internet survey with the same population but on a larger scale.

Internet surveys- The third approach for collecting data was by conducting an internet survey. The survey was designed for the rest of the project partners of EVOKED, both Stakeholders/practitioners, researchers, and the working groups or colleagues who are involved and relevant to the project EVOKED as well as some of the end-users of the climate services. The reason for including the survey was to verify the data received from the interviews as well as gain the perspective and knowledge about climate adaptation services and its potential usability gap of the other partners and stakeholders who were not interviewed. Furthermore, the survey was developed to collect the data and combine the results with the interviews by following the qualitative approach, which will provide validity to the research as well as verify the data collected from the interviews. To avoid repetition in the answers and the questions, a display logic was used for some of the questions in the survey by using Qualtrics software. The goal of this survey was to verify the perspectives of the interviewees on a larger scale. Few of the survey questionnaires also provided the respondents the opportunity to explain their perspective based on their selection of the closed-ended options. This confirmed an in-depth view of information that could be gathered from the participants of the survey. The method used to select the participants for the survey was a mixture of purposive sampling for the project partners and snowball sampling for the colleagues and working groups who are involved in the project EVOKED by forwarding the email, including the survey link. Following are the list of respondents from different organizations:

Place	**Organization**	**Survey sent**	**No. of participants responded**	**Response rate**
North Brabant, The Netherlands	• Deltares (Researchers) • Wageningen University/ Deltares (Researcher) • Province of North Brabant- Municipality (Stakeholder)	6 participants	6 participants	100 %

Drenthe, The Netherlands	• Drents Overijselse Delta, water board (Stakeholder) • Deltares (Researcher)	3 participants	1 participant	33.33%
Flensburg, Germany	• Christian-Albrechts University Kiel (Researcher) • City of Flensburg – Municipality (Stakeholder)	4 participants	4 participants	100%
Arvika, Sweden	• Värmland County Administrative Board- Municipality (Stakeholder) • Swedish Geotechnical Institute- SGI (Researcher)	2 participants	1 participant	50%
Larvik, Norway	• Norway Geotechnical Institute- NGI (Researcher) • Larvik Municipality (Stakeholder)	5 participants	5 participants	100%

Table 2: Overview of the Survey respondents

The survey was sent to a total of 16 project partners, including both stakeholders and researchers from each case study site of EVOKED. These project partners were then requested to send the survey to other working groups and colleagues who were involved in this project. Therefore, a total of 20 people received the invite to fill in the survey, and in total, only 17 of the participants responded, which is 85% of the total response rate. The designed survey can

be referred to in appendix 2. Furthermore, the surveys were analyzed using Qualtrics software. The details of this analysis will be mentioned in the section below.

3.4. Data Analysis:

The tool used to compare the climate change impacts in study areas, the focus of the climate services, and the relevant stakeholders involved in the case study area for the data analysis was Microsoft excel. Based on the literature review, theories, and the conceptual model, the interview guideline was designed. To conduct the interviews, online Skype business software and Google Hangout application were used. As it was essential to record the conversation during the interviews with the researchers and stakeholders from each case, an additional phone recorder, as well as a Skype business recorder, was used. This helped in avoiding any uncertainties in audio recording during the interviews. A qualitative data analysis program called the Atlas.ti software was used to transcribe and code the data collected from the semi-structured interview of the project partners of EVOKED based on the factors that influence the usability of the climate services. Codes are topics that are discussed with the participants of an interview and which are identified by reading the transcript (Hennink et al., 2011). The use of coding allows the researcher to identify topics and issues which can be raised in the interview as well as categories them based on themes (Cope, 2010). This helps the researcher to discover connections between issues raised in the interview and to place these within the context of the case study (Cope, 2010). Therefore, it is essential that the codes that are developed to analyze the transcripts, connect closely to the topics and issues raised in the research questions, so that the found information can help provide an answer to them (Cope, 2010). The used codes can be found in appendix 3.

Furthermore, a quantitative analysis program called the Qualtrics software was used to develop the survey as well as analyze the data collected from the different stakeholders who are involved in the decision making of climate adaptation services. However, due to a smaller number of respondents, the surveys were analyzed on Qualtrics software-data analysis qualitatively by combining the interviews and document analysis. The survey was also exported as a word document, which is attached in appendix 2.

Finally, the selected documents of EVOKED were also analyzed on Atlas.ti software by creating more relevant codes for specific themes as well as the codes used for the semi-

structured interviews. The list of codes used to analyze all the documents can be found in appendix 4.

The developed conceptual model helped in combining all the data gathered from the literature review, theories, existing records, workshops, documents of EVOKED, surveys, and interviews based on the codes and themes created in Atlas.ti software. Suitable solutions and recommendations were obtained after corresponding with all the data collected, providing an overview of all factors that are beneficial to improve the usability of the climate services for the future.

3.5. Validity and reliability of the research

"Reliability and validity are tools of an essentially positivist epistemology." (Watling, as cited in Winter, 2000, p. 7 and Golafshani, 2003)

The concept of validity and reliability revolves around trustworthiness, rigor, and the quality of the qualitative research approach (Golafshani, 2003). The way to achieve validity and reliability in research may get affected by a qualitative researcher's perspective by eliminating the biases and increase the truthfulness in the research proposition based on the social phenomenon and theories by including triangulation in the research (Golafshani, 2003; Denzin, 1978). As discussed in section 3.1, triangulation is considered to be a valid procedure where multiple sources of data collection are used to form themes and categories (Creswell & Miller, 2000, p. 126; Golafshani, 2003). Thus, according to a qualitative research point of view, reliability, validity, and triangulation are multiple ways of portraying good quality research with no biases and complete truthfulness (Golafshani, 2003).

To provide validity and reliability to this research, it was necessary to make a critical selection for the research methods, participants, and the choice of data collection that can be used in this research. Hence, a multiple case study strategy with qualitative research (documents, workshops, interviews, and surveys) was also chosen to confirm the triangulation of data by including a higher number of sources for data collection. The selection of participants was made by purposive sampling and snowball sampling for the interviews and surveys. This helped in gaining a more in-depth knowledge and perspective of relevant participants for this research. Furthermore, countermeasures were also taken while recording the interviews twice through different sources, so that any uncertainty or risks could be

avoided. Hence, this research could be valid and reliable for researchers who would further like to research this topic of climate adaptation services and its potential usability gap to improve the decision-making process, the usability of the climate services, and implement measures that are needed to adapt to climate change.

4. RESULTS AND ANALYSIS

In this section, the results obtained from the existing documents and records of the project EVOKED, workshop findings, as well as results from the interviews and surveys with the project partners (researchers and the practitioners/stakeholders) and the working groups, will be discussed for each case. These results will be based on the derived conceptual model (Fig. 7), to identify and analyze the factors influencing the usability of the climate services in each case study site.

4.1. Case study analysis

Each case study area will be discussed based on their location and demographics, the type of climate impacts in the region, existing climate services, usability gap, and the factors influencing the usability of climate services. The results of the workshop, survey, documents, and interviews will be presented for each case study site in a qualitative manner to discuss the factors influencing the usability of the climate service. A brief summary of the result will also be represented at the end of each case.

4.1.1. Larvik, Norway case study

The city of Larvik has the biggest municipality (in size) in Vestfold county. Also, Larvik has a 110km long coastline (EVOKED, *Larvik Deliverable 1.1c,* 2018). The 3rd longest river in Norway (Numedalslågen), runs through the city and the municipality from north to south, stretching for about 352kms (EVOKED, *Larvik Deliverable 1.1c,* 2018). Larvik is surrounded by many agricultural lands, forests, and hills. The geology consists of many igneous rocks from the Permian period (EVOKED, *Larvik Deliverable 1.1c,* 2018). Larvik has a population of about 47000 inhabitants, and most of them work in merchandising, transport, finance, and real estate (EVOKED, *Larvik Deliverable 1.1c,* 2018). Fig. 10 shows the location of the City Larvik.

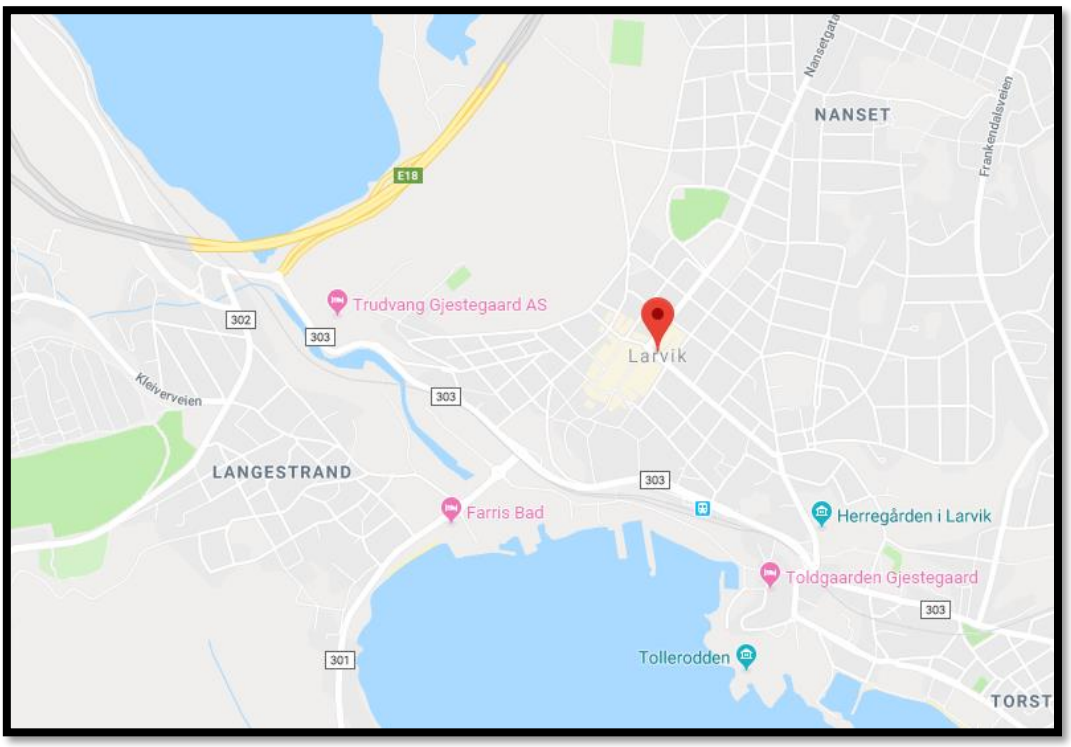

Fig. 10. The geographical location of Larvik, Norway (Google maps, 2019)

Larvik has ambitions to be an attractive and urbanized city in Norway. As most people want to live near the water, the municipality and city planners use this as a possibility to attract more people to consider moving to Larvik (NGI report, 2016). However, on the downside, there is a lot of wind and storm surges along with coastal and river flooding in Larvik, which is a risk for the inhabitants. Many residential buildings located near the coast have been damaged due to the recent storm events (NGI report, 2016). Recently, the impacts of climate change due to a range of natural hazards such as extreme rainfall, flooding, erosion, landslides, and storm surges were experienced (NGI report, 2016).

a) Existing climate services

Based on the analysis of EVOKED documents with respect to the city of Larvik, it was found that there is a frequent occurrence of severe floods, storm surges, and strong winds in Larvik. The increase in extreme precipitation is leading to an increase in the intensity of frequent urban flooding, erosion, quick clay slides, rock slides, coastal flooding (rise in sea-level), and river flooding. Due to these climate change impacts, the cost of damages is increasing day by day. To overcome these challenges, the municipalities, NGI, and other organizations are now mapping the climate impacts, and creating a framework for risk and

vulnerability assessments such as hazard and risk maps were recently developed, which also mentioned a few local adaptation and mitigation measures.

During the interview with one researcher from NGI and one stakeholder practitioner from Larvik Municipality, it was mentioned that at present, a few climate services such as hazard/risk flood maps are used. However, they do not have climate services that focus on all the climate impacts that Larvik is currently experiencing. It was also stated by the interviewees that, they are now developing a new climate service in regard to the blue-green infrastructure and urban development which will include adaptation measures for flooding, storm surge, etc. for essential target audiences such as real-estate developers, municipality, politicians, builders, and landscape architects. The goal of this climate service is action-oriented with respect to climate adaptation measures. This climate service will also have information about the economic aspects, i.e., the cost-benefit analysis for the city of Larvik.

During a workshop of EVOKED, information was gathered from the relevant project partners with respect to the Larvik Case study. This information was further analyzed and condensed to reflect relevant information pertaining to the existing climate services in Larvik. Table 3. shows the existing climate services in Larvik, the focus of the climate service, the various climate impacts in the region (Larvik municipality and Vestfold county), involved stakeholders, and the way these climate services are represented.

LOCATION	CLIMATE IMPACTS IN THE REGION	INVOLVED STAKEHOLDERS (Relevant climate impacts-Perception)	EXISTING CLIMATE SERVICES	FOCUS OF CLIMATE SERVICES-IMPACTS	INFORMATION PROVIDED BY THE CLIMATE SERVICES	REPRESENTATION OF THE CLIMATE SERVICES
Norway-Larvik	Extreme precipitation-flooding, storm surges, strong winds and snowmelt floods, quick clay landslides, rock and snow avalanche, debris flow	Martineåsen Landowners (Extreme precipitation-flooding)	Flood risk maps	Extreme precipitation- pluvial flooding, storm surges, debris flow, storm water runoff, droughts	Awareness and flood hazard comprehensive planning	Map, story map and conceptual illustration
Norway-Larvik (Vestfold County)		Construction Developers (Extreme precipitation-flooding)	Confidence building		Land- use management and flood risk management	Map, story map and conceptual illustration
		Politicians (Extreme precipitation-flooding)				

Table 3. Overview of Larvik's existing climate services analysis

In addition to the document analysis, interviews, and workshops, the existence of the two climate services (Flood risk-map and Confidence building tool) was also verified by conducting a survey with the four researchers and one stakeholder linked to the Larvik case study site.

b) Usability Gap

As observed in table 3, there exists a gap between the focus of the climate impacts on climate services and the actual climate impacts occurring in Larvik. Furthermore, the stakeholders perceive that only extreme precipitation is relevant, rather than all the other climate impacts mentioned in the table. The climate services also provide very limited information and only to a specific target group. Thus, understanding the knowledge needs and the perception of risk and uncertainty is significant for the Larvik municipality to explore and improve the visualization of the climate data produced in the climate services not only for the local authorities but also for the Larvik community. During the document analysis, it was found that there is a gap in capacity building and also a lack of awareness.

Furthermore, the stakeholders and the practitioners stated during the interview that improving the information provided based on the needs of the end-users, such as ambitious goals of urban development, is also highly necessary to reduce the usability gap, keeping in mind the effects of climate change. Improving communication and integrated collaboration between decision-makers is also another essential aspect that needs to be addressed through improved climate services. Some of the stakeholders also suggested during the interview that climate adaptation should be per area and not per property as this could create a gap in implementing the measures individually. They also suggested that climate adaptation measures must be included in all construction projects in Larvik. This will make people aware and educate them about the effects of climate change and how can it be dealt with, which will help in reducing the usability gap. The stakeholders suggested that better visualization of hazard/risk maps is needed, which will help them understand better, and it should also be user-friendly. There should be a continuous mapping of these vulnerable areas for all the natural calamities. Climate change information and adaptation measures should be included in climate services as well as during planning.

While analyzing the survey, it was found that most of the respondents stated that the usability gap is caused because of not being aware of the climate change impacts. However, one respondent suggested that this usability gap could also be caused due to not finding the

service convenient to use at a local scale. A common suggestion from the interviewees and the survey respondents was to develop more tools and products to increase awareness and make informed decisions based on specific vulnerable areas. All the 5 respondents stated in their survey that they feel that the climate services are moderately or not used at all and that the usability gap influences the decision-making process not only in the planning and understanding phase but also in the managing phase.

c) Factors influencing the usability of climate services

i) Target Audience:

Document Analysis: Based on the Larvik case study documents, it was observed that the target audience as a factor that influences the usability of the climate services was not explicitly mentioned. However, the only aspect that was stated was that the information provided by the climate services must be tailored according to the stakeholders' demands.

Interview analysis: At the Larvik case study site, The Interviewees have specified that the target audiences for them are primarily the planners, real-estate developers, politicians, builders, landscape architects, and municipalities. For a climate service to be useful to the end-users, it is essential that they are tailored according to the stakeholders' demands. Though it was mentioned during the interview that the information should be tailored according to the stakeholders' demands, not much emphasis was given to the 'target audience' to improve the usability gap.

Survey analysis: The comments from the respondents of the survey verified the results obtained from the interview. According to all 5 respondents, the lack of information needs of relevant stakeholders influences the usability gap. However, neither of the respondents emphasized the target audience as a factor for the usability gap.

ii) Information goal / purpose and Framing:

Document Analysis: Based on the Larvik case study documents, it was analyzed that the stakeholders' demands are primarily focused on the information based on climate adaptation measures and that the goal of the climate service must be necessary for raising more awareness and educating people about climate change. The information must consist of how to deal with climate change, when and where. Furthermore, according to the documents, the stakeholders feel that if the information is represented in a user-friendly manner and if the

information is framed in such a way that it is easier for the end-users to understand, then the usability of climate services will improve.

Interview analysis: According to the interviewees, information framing in climate services must be easy to understand and perceive for the end-users. Only then this knowledge transfer will improve the decision-making process and help in implementing suitable measures for climate change. Moreover, the interviewees feel that if the information goal of a climate service is more action-oriented in regard to climate change adaptation measures and the ways to implement it, then the usability gap can be reduced. Another critical aspect of information goal/ purpose that a climate service should provide, according to the interviewees, is to raise awareness and transfer knowledge.

Survey analysis: Based on the survey analysis, it was found that 4 out of 5 respondents stated that the goal of the climate services did not match with the goal of the stakeholder's demands, which could cause a usability gap. Furthermore, all the respondents agreed that the information goal/ purpose must be about raising awareness, educating people, and information based on climate adaptation measures. One of the respondents also suggested that the goal of the services could also be about changing cultural and social norms. In addition to this, all the respondents felt that the climate service should provide information that is easy to understand and perceive.

iii) DESTEP Model (Type of Information):

Document Analysis: According to the document analysis of Larvik, it was observed that the type of information which includes all the information aspects: demographic, social, economic, political, ecological, and technological is not necessary. The type of information that needs to be provided in a climate service must be according to the relevant stakeholder's demands.

Interview: Similar results were observed from the interview analysis as compared to the document analysis. According to the interviewees, economic aspects such as calculations in a cost-benefit analysis, are important types of information that the climate service should provide.

Survey: According to the survey respondents, most of them feel that the climate service should consist of information factors like climate data for vulnerable areas, such as the

DESTEP information aspects (Demographic, social, economic, political, technological, and ecological).

iv) Spatial/ Temporal information(action-oriented):

Document Analysis: Based on the document analysis, it was observed that the stakeholders find the need to create vulnerability and risk assessment frameworks due to current climate change impacts. Moreover, information based on implementing climate adaptation and mitigation measures is also an important aspect that the stakeholders demand.

Interview: However, during the interviews, it was observed that the interviewees did not feel the need to include the risk assessment frameworks in a climate service, and instead felt that it was essential to provide information on climate adaptation and mitigation measures in a climate service.

Survey: Same as the interview analysis, the respondents of the survey, stated that information on adaptation and mitigation measures could help to reduce the usability gap, rather than risk assessment frameworks and evacuation procedures.

v) Communication Channel:

Document Analysis: According to the document analysis, it was observed that improving communication and integrated collaboration between decision-makers is also an aspect that needs to be addressed through improved climate services. Two-Way communication is more effective than a one-way communication as it involves feedback loop, exchange of dialogues, surveys, field trials, and workshops to understand the stakeholder's demands to develop climate services and reduce the usability gap.

Interview: Both the interviewees stated that it is essential to have a feedback loop (two-way communication) during the process of developing a climate service to understand the various stakeholders' demands. Furthermore, exchanging knowledge and dialogues with stakeholders and decision-makers will also reduce the usability gap and increase awareness.

Survey: All the respondents of the survey feel that the two-way communication will help in reducing the usability gap and that at present, there is a lack of communication and coordination among the stakeholders.

vi) Representation:

Document Analysis: During the document analysis, it was found that there is a lack of visual representation (maps, 3D models, infographics, story maps, graphs, etc.) in the existing climate services based on the stakeholders' viewpoint. The stakeholders also feel that better visualization of hazard/risk maps is needed, which will help them to understand better, attract more stakeholders, and then implement measures. They also suggested that there should be a continuous mapping of these vulnerable areas for all the natural calamities.

Interview: The interviewees suggested that the usability gap can exist due to the lack of adequate visual representation. Both the interviews also think that the visual representation is more important than the information that is provided as it can attract more stakeholders to use it, but of course, they mentioned that the information provided needs to be tailored according to the stakeholders' demands and should be easy to understand.

Survey: None of the survey respondents felt that the visual representation could be a potential factor for influencing the usability gap between climate services and the end-users.

d) Summary: In this case study, there was no emphasis given to the target audience factor that could influence the usability of a climate service. However, it was observed that climate services must be tailored according to the stakeholder's demand in order to make informed decisions and implement adaptation measures. According to the result analysis, it was observed that not all the aspects of the DESTEP model (except economic information) is necessary for climate services. However, this type of information (DESTEP model) provided by the climate service must be tailored to the stakeholders' demands to improve the usability and in turn, make informed decisions about climate adaptation. Similarly, for the spatial/ temporal information factors, the emphasis was only given to the information on adaptation measures.

In terms of the information goal/purpose and the framing, it must be easy to understand as well as user-friendly. Raising awareness and exchanging knowledge are some important aspects of the information goal of the service to improve the usability gap. Moreover, through two-way communication, services can be improved and monitored. Visual representation of the information through 3D-models, story maps, pictures, infographics, etc. will attract more stakeholders to use the climate service.

During the interviews and the survey, it was analyzed that the interviewees and the respondents also stated a few other potential factors that could cause the usability gap between the climate services and the end-users. External factors such as behavioral issues/ participatory issues, governance issues at different levels, lack of taking responsibility, lack of political willingness, lack of resources (finance, time, technology, etc.), and lack of awareness were mentioned while conducting this research by the practitioners and the stakeholders.

4.1.2. Arvika, Sweden case study

The city of Arvika lies in the region of Värmland by Lake Kyrkviken in Sweden (Österlind, 2019). Arvika has the largest settlement in the municipality (Österlind, 2019). As of 2017, the population at Arvika is about 20,060 people (Österlind, 2019). The area of the Arvika municipality is 16,449 km2 (Österlind, 2019). Arvika faces several climate change challenges such as flooding events, drainage system overload, and poor quality of surface waters (Österlind, 2019). In the year 2000, the city experienced a 100-year flood event with damages estimated to be over 30 million EUR (EVOKED-*Arvika_VCAB 1.1 E*, 2018). Fig.11 shows the geographical location of Arvika.

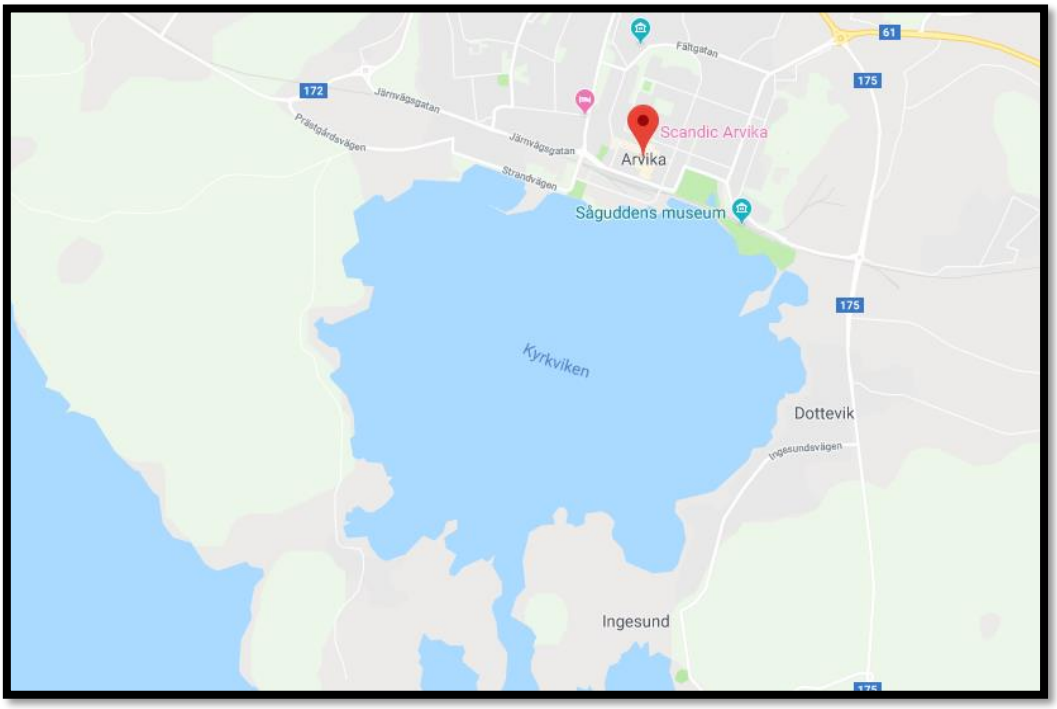

Fig.11 The geographical location of Arvika, Sweden (Google maps, 2019)

Similar to Larvik in Norway, people in Arvika also are attracted to live near the water areas. Therefore, there is a need for building new sustainable and energy-efficient housing,

which can also protect the existing structures against flood events (Österlind, 2019). Furthermore, it is also essential to improve the water quality of Kyrkvika lake so that it can be used as a good drinking water source as well as people could swim in it (EVOKED-*Arvika_ VCAB 1.1 needs and vision*, 2018). There is also a need to take adaptation measures during cloudburst events, which could cause flooding and landslides (Österlind, 2019). In Arvika, most people don't think about risks and measures to be taken to adapt to the challenges of climate change, even though there were two major flood events recently in the year 2000 and 2014 (EVOKED-*Arvika_ VCAB 1.1 E*, 2018).

a) Existing climate services

Arvika is exposed to water (the rivers, the lake Vänern, the city of Karlstad situated on a delta) and has experienced several floods and landslides. The city has adapted to become sustainable and energy-efficient. However, it still lacks in becoming more climate adaptive. Certain climate services in Arvika deal with the quality of Lake Kyrkviken (EVOKED-*Arvika_ VCAB 1.1 needs and vision*, 2018). These also include the construction of a flood barrier, a flood risk map, and improved drainable system, urban rain depth models, creating a "green" city plan, involvement in the CATCH project (Reduction of Climate Effects on Water Quality) (EVOKED-*Arvika_ VCAB 1.1 needs and vision*, 2018).

To overcome climate change challenges, VCAB (Varmland County Administrative Board) in collaboration with SGI (Sweden Geo-technological Institute), NGI (Norway Geo-technological Institute), and Arvika municipality is trying to make efforts to adapt to climate change by finding ways to communicate the integrated risks, increasing knowledge and raising awareness associated with climate change. The collaboration is also trying to develop different kinds of information channels on the topics of flooding by using digital solutions, for the municipality of Arvika.

During the interview with one researcher from SGI and one stakeholder/practitioner from Värmland County Administrative Board- Municipality, it was mentioned that climate service is a source or tool that consists of relevant climate data that can be used to make informed decisions for climate adaptation measures. Currently, the aforementioned Interviewees are developing a climate service which is in the form of a story map for the municipality of Arvika. The service focuses on flooding issues, past experiences of flooding, changed water quality, extreme precipitation, agricultural runoffs, and adaptation measures. The story map comprises many flood maps and different climate-related

scenarios, which is essential for politicians to use so that they can understand the consequences of climate change. The story map is targeted towards political leaders, municipalities, and planners. However, it is accessible to everyone. The respondents said that in the story map, they are including some demographic information, social information, and some environmental information.

During a workshop of EVOKED, information was gathered from the relevant project partners with respect to the Arvika Case study. This information was further analyzed and condensed to reflect relevant information pertaining to the existing climate services in Arvika. Table 4 shows the existing climate services in Arvika, the focus of the climate service, the various climate impacts in the region (Arvika municipality and Värmland county), involved stakeholders, and the way these climate services are represented.

LOCATION	**CLIMATE IMPACTS IN THE REGION**	**INVOLVED STAKEHOLDERS (Relevant climate impacts-Perception)**	**EXISTING CLIMATE SERVICES**	**FOCUS OF CLIMATE SERVICES-CLIMATE IMPACTS**	**INFORMATION PROVIDED BY THE CLIMATE SERVICES**	**REPRESENTATION OF THE CLIMATE SERVICES**
Sweden-Värmland (Arvika)	Fluvial flooding, landslides, forest fires, changed water quality, pluvial flooding, and droughts	Värmland County Administrative Board (VCAB) (Heat stress, forest fires, droughts, extreme precipitation, and flooding)	Länsvisa Klimatanalyser (SMHI- Regional climate analyses)	Fluvial flooding, pluvial flooding and changed water quality	Information on extreme precipitation, extreme temperature, climate scenarios, and soil saturation	Reports and web-based maps in wms-or shape format

Sweden-Värmland (Arvika)		All other municipalities in Värmland County (Heat stress, forest fires, droughts, extreme precipitation, and flooding)	Översvämning vattendrag och kust (MSB)- Flood maps of watercourses and coastal		Flood risk management with time scale and climate adaptation plans	Reports and web-based maps in wms-or shape format
Sweden-Värmland (Arvika)		Teknik i Väst AB (Arvika Teknik AB) (Extreme precipitation, flooding, changed water quality)	Översiktlig stabilitetskartering i finkorniga jordarter (MSB)- Mapping of slopes in fine-grained soil		Landslide risk assessment and slope stability	Reports and web-based maps in wms-or shape format
Sweden-Värmland (Arvika)		Swedish Church landowners in Arvika (Extreme precipitation and flooding)	Regional Planning Catalog (Lst Planeringskatalog) and Geodataportalen (and BoV Tillsynvägledning		Urban planning, Geotechnical risk, and climate adaptation plans	Reports and web-based maps in wms-or shape format

Table 4. Overview of Arvika's existing climate services analysis

In addition to the document analysis, interviews and workshops, the existence of the 4 climate services (Länsvisa Klimatanalyser (SMHI- Regional climate analyses), Regional Planning Catalog (Lst Planeringskatalog) and Geodataportalen (BoV Tillsynvägledning), Översvämning vattendrag och kust (MSB) - Flood maps of watercourses and coastal, Översiktlig stabilitetskartering i finkorniga jordarter (MSB) - Mapping of slopes in fine-grained soil) were also verified by conducting a survey with the one stakeholders linked to the Arvika case study site.

b) Usability Gap

As observed in table 4, there exists a gap between the focus of the climate impacts in the climate services and the actual climate impacts occurring in Arvika. Most of the stakeholders perceive extreme precipitation, change water quality, and flooding relevant rather than all the other climate impacts mentioned in the table. The climate services also provide very limited information and only to a specific target group.

During the document analysis of the Case study site Arvika, the stakeholders feel the need for more flood protection and communication tools to raise awareness, transfer knowledge, take responsibility when climate change incidents occur, encourage collective narratives about the past events, disaster risk management, and evacuation plans. Relevant and adequate information in the climate services, data about fluvial flooding, climate adaptation strategies, and resilient urban development are also some of the other stakeholder demands. Most of the stakeholders emphasize on improving the water quality and implementing more climate adaptive measures.

Even though so much data and knowledge are available through climate services, there is a gap in understanding this information, perceiving it, and then applying or acting on it (EVOKED-*Arvika_VCAB 1.1 needs and vision*, 2018). Furthermore, raising awareness at a macro-level among the locals about the risks and uncertainty of climate change is essential, so that people can start thinking about it and implement measures that could protect them from flood event or any natural calamities. This will also bring a sense of security among the residents (EVOKED-*Arvika_VCAB 1.1 needs and vision*, 2018). Communicating this information and raising awareness to the locals is essential, which can be done through climate services, and the involved stakeholders can initiate these measures.

Thus, we can see the reason for the usability gap, which is lack of appropriate knowledge, lack of awareness, lack of information (Demographic, social, economic, political, technological and ecological aspects), lack of perception of climate-related risks, lack of communication and lack of better visual representation. Hence, understanding the knowledge needs and the perception of risk and uncertainty is essential for the Arvika municipality to explore and improve the visualization of the climate data produced in the climate services not only for the local authorities but also for the local community.

Furthermore, the stakeholders and the practitioners also stated during the interview that there is a lot of data that is available. However, it is difficult to measure the usability of climate services. They also stated that if there is too much data available, it becomes difficult to understand and apply them effectively, and then only an expert can make use of it. Both the interviewees mentioned that there is a usability gap, and this could be reduced if the information is filtered, easy to understand, relevant to the stakeholder's demands and if the climate services are user-friendly. According to the respondents, awareness of climate change impacts to some extent does exist, but the information on social, economic, political aspects is lacking, and that is why the goal is not achieved most of the time, which leads to the usability gap. The interviewees suggested that competence building, filtering and transforming the information that is easily understandable, and implementing or having the information of the best practices for the community could be a way to bridge the gap.

Additionally, there was only one respondent (stakeholder) for the survey who stated that the lack of resources (finance, time, and technology) could also influence the decision-making process and the usability of the climate services negatively. However, since only one response was received from a stakeholder from VCAB, and the respondent did not completely fill the survey, the results of this survey are inconclusive for this particular case study area.

c) Factors influencing the usability of climate services

i) Target Audience:

Document Analysis: Based on the Arvika case study documents, it was analyzed that the climate services must be tailored according to the stakeholders' demands and must also provide minimal information which is tailored for a specific target group.

Interview analysis: At the Arvika case study site, the Interviewees specified that the target audiences for them are primarily the political leaders, municipalities, and planners; however, all the climate services are accessible to everyone. For a climate service to be useful to the end-users, it is essential that they are tailored according to the stakeholders' demands. However, the interviewees did not emphasize the aspect of the target audience precisely, which could influence the usability of climate services as a factor.

ii) Information goal / purpose and Framing:

Document Analysis: Based on the Arvika case study documents, it was analyzed that the stakeholders' demands are primarily focused on the information based on climate adaptation

measures and that the goal of the climate service must be mainly for raising more awareness, educating people about climate change and implementing climate adaptation measures. Furthermore, according to the documents, there was nothing mentioned about the information framing.

Interview analysis: According to the interviewees, information framing in climate services must be easy to understand and perceive for the end-users. They also stated that the information framing should not be very technical, and instead, it must be user-friendly for the end-users. Only then this knowledge transfer will improve the decision-making process and help in implementing suitable measures for climate change. Moreover, the interviewees feel that the information goal of a climate service must be mainly for raising more awareness, educating people about climate change, and implementing climate adaptation measures.

iii) DESTEP Model (Type of Information):

Document Analysis: According to the document analysis of Arvika, it was observed that there is a lack of the type of information which includes all the information aspects: demographic, social, economic, political, ecological, and technological in this case study site. Furthermore, it was also observed during the document analysis that the type of information provided in a climate service must be according to the relevant stakeholder's demands and should be specific to the target audience.

Interview analysis: According to the interviewees, the information on social, economic, political aspects is lacking, and that is why the goal is not achieved most of the time, which leads to the usability gap. The interviewees also said that the newly developed climate service- the story map would include some demographic information, social information, and some environmental information as it's according to the stakeholder's demands, which is what a climate service must entail.

iv) Spatial/ Temporal information(action-oriented):

Document Analysis: Based on the document analysis, it was observed that there was nothing mentioned about the spatial/temporal factors such as risk assessment framework or evacuation procedures. The only aspect that the stakeholder's demand is the information on climate adaptation measures, which the documents specify and is as an important aspect for climate services to provide.

Interview analysis: Similar results were obtained during the interview, as the interviewees did not feel the need to include the risk assessment frameworks in a climate service, and instead felt that it was essential to provide information on climate adaptation measures in a climate service.

v) Communication Channel:

Document Analysis: According to the document analysis, it was observed that stakeholder's vision for Arvika is to have a better quality of life, feel safe by increasing coordination and communication among relevant parties for making informed decisions, raise awareness and knowledge among the locals, and implement more climate adaptation measures so that the residents feel secure from the effects of climate change. The stakeholders also need more communication tools to raise awareness and knowledge. Thus, two-way communication is more effective than a one-way communication as it involves feedback loop, exchange of dialogues, surveys, field trials, and workshops to understand the stakeholder's demands to develop climate services and reduce the usability gap.

Interview analysis: According to the interviewees, most of the climate services have one-way communication, however, according to them it is important to have a feedback loop (two-way communication) during the process of developing a climate service to understand the various stakeholders' demands as well as improving the climate services after being developed. Furthermore, exchanging knowledge, collective narratives, and dialogues with stakeholders and decision-makers will help in improving the coordination and collaboration among the stakeholders as well as reduce the usability gap and increase awareness.

vi) Representation:

Document Analysis: During the document analysis, it was found that there is a lack of visual representation (maps, 3D models, infographics, story maps, graphs, etc.) in the existing climate services based on the stakeholders' viewpoint. It was also observed that if the information is represented in an easy and user-friendly manner, with adequate graphics, then more stakeholders will be attracted to use the climate service.

Interview analysis: The interviewees suggested that the usability gap can exist due to the lack of adequate visual representation. Both the interviewees also feel that better visualization through story maps will help them to understand and perceive the information better, relate

to past events and experiences, and better, attract more stakeholders and then implement measures.

d) Summary: In this case study, it was observed that the type of information provided by the climate service might not include all the DESTEP factors; however, based on the stakeholders' demands, the information must be provided in a climate service. According to the stakeholders and researchers, mostly social, economic, and environmental factors must be included in a climate service. Similarly, the data gathered from the documents and interviews did not mention anything about the spatial/ temporal information to be an essential factor for influencing the usability gap, except for the information on climate adaptation measures is necessary to be included in a climate service.

In terms of target audience being and essential factors influencing the usability of climate services, it was observed that the climate services must be tailored according to the stakeholder's demand in order to make informed decisions, implement adaptation measures, and reduce the usability gap. Moreover, raising awareness and exchanging knowledge are some essential aspects of the information goal of a climate service to improve the usability gap. It is essential to provide information that is filtered, easy to understand, perceive, and not too technical for the end-users of climate services. A lot of emphases were given to the mode of communication and visual representation in this case study. Through two-way communication, services can be improved and monitored. Visual representation of the information through 3D-models, story maps, pictures, infographics, etc. will attract more stakeholders to use the climate service.

Furthermore, it was also observed that it is essential for stakeholders to collaborate and take responsibility during the decision-making process and the implementation of climate adaptation measures. During the interviews and the survey, it was analyzed that the interviewees and the respondents also stated a few other potential factors that could cause the usability gap between the climate services and the end-users. External factors such as behavioral issues/ participatory issues, governance issues at different levels, lack of taking responsibility, lack of political willingness, lack of resources (finance, time, technology, etc.), and lack of awareness were mentioned while conducting this research by the practitioners and the stakeholders.

4.1.3. City of Flensburg, Germany case study

Flensburg is situated in the northern part of the German state Schleswig-Holstein and is the third-largest town in the state of Schleswig-Holstein (EVOKED, *Territorial, and governance- Flensburg*, 2018). Flensburg lies at the innermost tip of the Flensburg Fjord, an inlet of the Baltic Sea. The City of Flensburg is spread over 5.674 ha (56 km2), and as of 2016, the total population was about 94,227 people ("Strukturdaten der Stadt Flensburg," 2019). The city is situated 12m above sea level, but there are low lying regions around the Flensburg Fjord (EVOKED, *Territorial, and governance- Flensburg*, 2018). This region is highly prone to risks such as the sea-level rise and coastal flooding. Fig.12 shows the geographical location of the City of Flensburg.

Fig. 12 The geographical location of the City Flensburg (Google maps, 2019)

As seen in the map, the city of Flensburg is very close to the Baltic sea, and this makes the city and its inhabitants prone to climate change events like sea-level rise, storm surges, extreme precipitation, floods, etc. (EVOKED, *Territorial and governance- Flensburg*, 2018). Furthermore, the city center, which is in the valley between the slopes of the Flensburg fjord

is characterized by a range of usages (e.g. mobility, trade, and tourism), and is the area being most at risk of sea-level rise and associated flooding (EVOKED, Territorial and governance- Flensburg, 2018). According to the interviewees, storm surges, extreme precipitation, sea-level rise, and flooding are the major climate threats to the city of Flensburg. To tackle these challenges, climate adaptation measures are being implemented in the city of Flensburg. Since Flensburg is a small city and is located near the coast, they do not face much heat problems like the bigger cities (Berlin, Hamburg, etc.) in Germany.

a) Existing climate services

Since the City of Flensburg is situated at the coast and some of the parts are low lying areas, there is a high risk of climate change impacts such as a rise in sea level, extreme precipitation, coastal flooding, and erosion. The cities and communities are responsible for climate adaptation plans and strategies. Depending on the measures that need to be implemented, the responsibility will be on the state or community level (EVOKED, Territorial, and governance- Flensburg, 2018). Thus, the municipality into-operation with local stakeholders is now initiating the process of developing climate adaptation agendas. It is essential that the locals are entirely aware of the risks and uncertainties of climate change and how to deal with these challenges (EVOKED, Territorial, and governance- Flensburg, 2018).

The regional governance level (State Schleswig-Holstein) provides general information about the impacts of climate change and adaptation to climate change, flood risk management plans, and flood maps (EVOKED, Needs, and vision- Flensburg, 2018). The first scientific information about sea-level rise and other climate impacts in Flensburg was provided by the North German Climate Office in January 2017 (EVOKED, Territorial, and governance- Flensburg, 2018). Adaptation policies are not available at a local level and nor are there any current information on the assessment of vulnerability for coastal flooding for Flensburg, and in addition to this, no measures have been implemented. Thus, during the interview with one researcher from Christian-Albrechts University Kiel and one practitioner from the City of Flensburg- municipality, it was mentioned that they have already taken measures to protect the city from heat stress, by planting trees and building other cooling infrastructures. Currently, the aim of their climate service is to rebuild and re-design the seaside of Flensburg to protect it from the impacts of climate change like storm floods, sea-level rise, etc. As, according to interviewees, climate protection strategies, policies, and

adaptation measures should be implemented now. The 4 climate services that are in the process of development are climate impact assessment, socio-economic scenarios for Flensburg, flood maps (help in decision-making process for re-designing the seaside of Flensburg) and story maps which consists of some background information, real-life past experiences represented in the format of maps, texts, graphs, and pictures. This will also help in raising awareness among the inhabitants of Flensburg. It also consists of adaptation measures and innovative ideas of sustainable urban development.

During a workshop of EVOKED, information was gathered from the relevant project partners with respect to the Flensburg Case study. This information was further analyzed and condensed to reflect relevant information pertaining to the existing climate services in Flensburg. Table 5 shows the existing climate services in Flensburg, the focus of the climate service, the various climate impacts in the region, involved stakeholders, and the way these climate services are represented.

LOCATION	**CLIMATE IMPACTS IN THE REGION**	**INVOLVED STAKEHOLDERS (Relevant climate impacts-Perception)**	**EXISTING CLIMATE SERVICES**	**FOCUS OF CLIMATE SERVICES-CLIMATE IMPACTS**	**INFORMATION PROVIDED BY THE CLIMATE SERVICES**	**REPRESENTATION OF THE CLIMATE SERVICES**
Germany-Flensburg	Extreme precipitation, coastal flooding, droughts, sea-level rise, land subsidence, increase in cyanobacteria due to rise in temperature	Division of city development, City of Flensburg (sea-level rise)	Flood hazard and flood risk maps Schleswig-Holstein	Sea-level rise and coastal flooding	Hazard and risk management with time scale (sea-level rise and coastal flooding)	Online maps with meta- information

		Private business (sea-level rise)	North German Climate Atlas		Sea-level rise, coastal flooding, High temperature, and climate scenarios projections-modeling for ranges	Online maps with regional projects-tables and graphs
		Citizen (sea-level rise)	Climate adaptation Roadmap of Schleswig-Holstein		NAS sector, coastal flooding, and erosion, sea-level rise and storm surges-water, coastal and agricultural management	Brochure and online document with tables, graphs, and texts
		Nature protection agency (sea-level rise)	Baltic Sea Coast and Climate Change Handbook		Changes and predictions (Cloudage, wind, seasonal changes and warming of Baltic sea, sea-level rise, storm surges, and coastal erosion) - coastal and marine ecosystem management	Brochure and online document with texts

Table 5. Overview of Flensburg's existing climate services analysis

In addition to the document analysis, interviews and workshops, the existence of the 4 climate services (Flood hazard and flood risk maps Schleswig-Holstein, North German

Climate Atlas, Climate adaptation Roadmap of Schleswig- Holstein and Baltic Sea Coast and Climate Change Handbook) were also verified by conducting a survey with three researchers and one stakeholder linked to the Flensburg case study site.

b) Usability Gap

As observed in table 5, there exists a gap between the focus of the climate impacts on climate services and the actual climate impacts occurring in Flensburg, such as the climate services do not have information on droughts, land subsidence and the increase in cyanobacteria in the water bodies due to high temperature. Furthermore, there are no existing climate services at a local level, which becomes difficult for the stakeholders to implement measures at a local level. Another issue is that when there is an excess of data available, the end-users have difficulty in understanding the information provided and using it to make informed decisions or implement suitable measures.

As mentioned before that climate adaptation policies and information on the assessment of vulnerability to coastal flooding are not available at the local level, there is limited knowledge that exists in regard to this topic (EVOKED, Territorial and governance- Flensburg, 2018). Furthermore, through analyzing the documents for the Flensburg case study area, it was observed that the local stakeholders do not seem to favor the classical protection strategies, in the form of engineered and built options in the city, but instead appear more positive to alternative adaptation options for coping with the future flood risk (EVOKED, Territorial and governance- Flensburg, 2018). It is also stated in the documents that when all the actors come together during the implementation of the development, conflicts arise in the decision-making phases.

During the interview, the interviewees stated that there are many climate services available for the whole country as well as the region but not locally for each city. This could potentially create an issue for informed decision-making and implementation of measures on a local scale. Furthermore, they stated that there are flood maps on a federal level but not on a local scale, especially for sea-level rise in Flensburg. When asked to what extent the climate services are used, the interviewees responded, saying that at present, as the information is fundamental and there aren't any maps or road maps for sea-level rise or storms as of now, which is also scientific information. So, measuring the usability gap of the service is difficult at the moment since there is no information available at a local scale. However, one significant difference in the survey response was that the stakeholder mentioned that the

climate services weren't being used at all, whereas the researchers said that they were used most of the time. According to the interviewees, if there is too much data available it becomes difficult to understand and apply them effectively, and then only an expert can make use of it. Thus, the information needs of a stakeholder for climate service must be filtered and must provide scientific information but not too technical, easy to understand, and read, and it should be user-friendly. But during the survey, one of the respondents (stakeholder) stated that climate services are not user-friendly at all. According to the interviewees, awareness of climate change impacts to some extent does exist, but the information on social, economic, political aspects is lacking, and that is why the goal is not achieved most of the time, which leads to the usability gap. The interviewees suggested that competence building, filtering and transforming the information that is easily understandable, and implementing or having the information of the best practices for the community could be a way to bridge the gap.

All the survey respondents and interviewees mentioned that two-way communication, better visual representation and adequate, relevant information tailored according to the stakeholder's needs must be provided by the climate services to improve the usability of a climate service.

The challenges that the City of Flensburg faces is lack of integrated participation, coordination, awareness, concrete decisions which involve political, demographic and societal aspects, and information on solutions and opportunities for climate adaptation. There also arises a conflict of interest among stakeholders, as well as the lack of residents' trust and acceptance (EVOKED, Territorial, and governance- Flensburg, 2018). Hence, to avoid all these barriers, information must be available at a local level in regard to climate adaptation measures to prevent flood events and promote proactive actions (plan how to react and cope with flood risk, particularly in the city centre, and integrate it in future adaptation planning with long term measures). Raising awareness among the locals, developing trust and acceptance among the stakeholders as well as the citizens, and making informed/concrete decisions are few other aspects that could help in overcoming the challenges.,

Additionally, the survey respondents (1 stakeholder and 3 researchers) stated that the lack of resources (finance, time, and technology), lack of integrated participation, coordination, awareness, concrete decisions could also influence the decision-making process and the usability of the climate services negatively.

c) Factors influencing the usability of climate services

i) Target Audience:

Document Analysis: Based on the Flensburg case study documents, it was analyzed that the information provided in climate services must be tailored according to the stakeholders' demands and to a specific target group/ audience. Tailoring the information for a specific audience is necessary because an abundance of data may overwhelm the end-user and can cause misunderstandings.

Interview analysis: At the Flensburg case study site, the interviewees specified that the target audiences for them are primarily the municipalities, planners, private businesses, the national protection agencies, and the local citizens. For a climate service to be useful to the end-users, it is essential that they are tailored according to the stakeholders' demands.

Survey analysis: After analysing the data received from the respondents of the survey (1 stakeholder and 3 researchers), it was observed that it is essential to tailor the information provided in a climate service only to a specific group/ target audience and that the information must be tailored according to the stakeholders' needs to reduce the usability gap.

ii) Information goal / purpose and Framing:

Document Analysis: Based on the Flensburg case study documents, it was analysed that the stakeholders' demands are primarily focused on the information based on climate adaptation measures and that the goal of the climate service must be mainly for raising more awareness, educating people about climate change, promoting proactive behavior and implementing climate adaptation measures. Furthermore, according to the documents, the information provided in the services must be easy to understand and accessible to everyone.

Interview analysis: According to the interviewees, information framing in climate services must be easy to understand and perceive by the end-users. They also stated that the information must be scientific but not too technical, but this must also depend on the target audience. The information must also be user-friendly for the end-users. Moreover, the interviewees feel that the information goal of a climate service must be mainly for raising more awareness, educating people about climate change, promoting proactive behavior, and implementing climate adaptation measures.

Survey analysis: However, the respondents did not emphasize much on the information goal as a factor that could influence the usability of a climate service. Only 2 out of 4 respondents stated that the information must be concerned with raising awareness about the climate impacts, and the framing of the information should be easy and attractive for the end-users to read and understand.

iii) DESTEP Model (Type of Information):

Document Analysis: According to the document analysis of Flensburg, it was observed that there is a lack of the type of information which includes all the information aspects: demographic, social, economic, political, ecological, and technological in this case study site. Furthermore, during the document analysis, it was found that most of the stakeholders from Flensburg felt that information based on social, economic, demographic aspects is essential in a climate service.

Interview analysis: According to the interviewees, the information on social, economic, demographic, and political aspects is lacking, and that is why the goal is not achieved most of the time, which leads to the usability gap. The interviewees also said that in the newly developed climate service- socio-economic assessment framework and the climate impact assessment include some demographic information, social and economic information, as well as some environmental information as it is according to the stakeholders' demands, which is what a climate service must entail.

Survey analysis: Only two survey respondents stated that the DESTEP model information is essential in a climate service. In addition to this, they also stated that depending on the stakeholders' demands that climate service should provide this type of information (DESTEP). However, the respondents did not specify which of these DESTEP information plays an important role in reducing the usability gap between the climate services and the end-users.

iv) Spatial/ Temporal information(action-oriented):

Document Analysis: Based on the document analysis of the Flensburg case study, it was observed that the spatial/temporal factors such as risk assessment framework, evacuation procedures, and climate adaptation measures are essential in a climate service. The only aspect that the stakeholder's demand is the information on climate adaptation measures, which the documents specify and is as an important aspect for climate services to provide.

Interview analysis: Similar results were obtained during the interview, as the interviewees felt the need to include the climate impact risk assessment frameworks and information on climate adaptation measures in a climate service. However, the interviews did not feel the need to include evacuation procedures in the newly developed climate services.

Survey analysis: However, during the analysis of the survey, none of the participants responded to the spatial/temporal aspect as a factor that could influence the usability of climate service. The respondents did not feel the need to include this information in the climate services as there could be other specific services/ tools that tailor to this information.

v) Communication Channel:

Document Analysis: According to the document analysis, it was observed that most of the climate services have one-way communication, which potentially causes the usability gap. Thus, having a two-way communication is essential to reduce the potential gap, as it includes workshops, field-trials, interviews (with relevant stakeholders), feedback loops along with the services, and online surveys while developing the climate services to understand the stakeholder's needs.

Interview analysis: According to interview analysis, both the interviewees stated that it was essential to include an effective communication system to avoid misunderstandings. Two-way communication is essential to reduce the potential gap as it includes workshops, feedback loops, and online surveys while developing climate services. This process will help in understanding the needs of the stakeholders/end-users to develop better climate services, improve/ monitor the existing services, which helps in improving the usability of a climate service. Encouraging the exchange of knowledge, collective narratives, and risk dialogues also help in better communication and improve coordination-collaboration among the end-users.

Survey analysis: All the respondents stated that two-way communication is much more effective than a one-way communication system. Furthermore, they also stated that there is a lack of communication in the existing services, which needs immediate attention and improvement to avoid the usability gap.

vi) Representation:

Document Analysis: During the document analysis, it was found that there is a lack of visual representation (maps, 3D models, infographics, story maps, graphs, etc.) in the existing climate services based on the stakeholders' viewpoint. Most of the stakeholders felt the need

to have climate services that are visually attractive and readable. It was also observed from the documents that climate services with texts and graphics are more widely used by the end-users, as it attracts them and also helps them understand the information better.

Interview analysis: The interviewees suggested that the usability gap can exist due to the lack of adequate visual representation. Both the interviewees also feel that better readability and visualization of information and real-life past experiences represented in the format of maps, texts, graphs, pictures, etc. will help in raising awareness even among the inhabitants.

Survey analysis: Similar results were obtained from the survey, as all the respondents stated that there is a lack of visual representation in the climate services and that there is a need to have better visualization and readability of the information provided in the climate service.

d) Summary: Overall, for the case of Flensburg, there is a need for adequate and relevant information for climate services, especially at a local level. Climate services that mainly consist of information on the sea-level rise are essential for the City of Flensburg to tackle climate impacts.

In order to bridge the gap, the decisions must be more concrete, develop trust and acceptance among the stakeholders as well as the inhabitants and promote proactive actions (plan how to react and cope with flood risk, particularly in the city center, and integrate it in future adaptation plans which are long term measures). In addition to this, decision-making processes and the implementation of adaptive measures should be as political, democratic, and participative as possible. Furthermore, readability, better visual representation, information that is easy to understand, two-way communication, information on adaptation measures/climate risk assessments and raising awareness among the locals by developing more similar services are some of the factors that needs to be implemented while developing a climate service to reduce the usability gap between the climate services and the end-users. In terms of the target audience as a factor, it was observed that the information must be tailored according to a specific target audience or the stakeholder's demands who are using the climate services. The information goal must be mainly about educating and raising awareness about climate change impacts and the ways to tackle it.

In this case study, it was observed that the type of information provided by the climate service might not include all the DESTEP factors; however, based on the stakeholders' demands, the information must be provided in a climate service. According to the

stakeholders and researchers, mostly social, economic, demographic, and environmental factors must be included in a climate service. Similarly, the data gathered from the documents and interviews did not mention anything about the spatial/ temporal information to be an essential factor for influencing the usability gap, except for the information on climate adaptation measures and risk assessment frameworks that are necessary to be included in a climate service.

The interviewees and the respondents also stated a few other potential factors that could cause the usability gap between the climate services and the end-users. External factors such as behavioral issues/ participatory issues, governance issues at different levels, lack of taking responsibility, lack of political willingness, lack of resources (finance, time, technology, etc.), and lack of awareness were mentioned while conducting this research by the practitioners and the stakeholders.

4.1.4. North Brabant, The Netherlands case study

The Province of North Brabant has a population density of 501 people per km² ("Noord-Brabant" *Wikipedia*, 2019; EVOKED, *Deliverable.3.2 NB v2*, 2019). Noord-Brabant has a population of 2,463,720 people ("Noord-Brabant" *Wikipedia*, 2019). The most urbanized part of Noord-Brabant is its center, where the cities of Breda, Tilburg, Eindhoven, and ‘s Hertogenbosch are located. North-Brabant is a flat province, which is located above sea level ("Noord-Brabant" *Wikipedia*, 2019; EVOKED, *Deliverable.3.2 NB v2*, 2019). A lot of this area in the past also consisted of forests and agricultural lands ("Noord-Brabant" *Wikipedia*, 2019). The northern border of the province is demarcated by the Maas river and the Merwede ("Noord-Brabant" *Wikipedia*, 2019; EVOKED, *Deliverable.3.2 NB v2*, 2019). These rivers are important transport routes for shipping traffic ("Noord-Brabant" *Wikipedia*, 2019; EVOKED, *Deliverable.3.2 NB v2*, 2019). The same is true for canals such as the Zuid-Willemsvaart, the Maximakanaal, and the Wilhelminakanaal ("Noord-Brabant" *Wikipedia*, 2019; EVOKED, *Deliverable.3.2 NB v2*, 2019). The following maps depict the geographical region of North Brabant. Fig. 13 shows the geographical location of the North Brabant region, The Netherlands.

Fig 13. The geographical location of North Brabant region, The Netherlands (Google maps, 2019)

In terms of climate impacts, North Brabant faces several of them, such as extreme precipitation, which leads to both pluvial flooding in mostly urban areas, and fluvial flooding from the regional water system or river floods (EVOKED, *Deliverable.3.2 NB v2*, 2019). Additionally, droughts are also a potential risk in this area during the summers, which will, in turn, lead to heatwaves (PBL, 2013). Both pluvial and fluvial flooding leads to extreme damage to the properties, buildings, disruption of traffic, water overflowing on the dikes and also the streets, dike breaching even casualties, etc., similar to the past incident in Boekel (Udens Weekblad, 2016). The North-east Brabant is the region where there are many agricultural fields and due to the scorching weather during summers, it affects the surface water quality which leads to a decrease in drinking water as well as a decrease in the groundwater levels during droughts which leads to soil subsidence (Didde, 2018; Aan de Brugh, 2019). Heatwaves are another issue of climate change, which can lead to higher temperatures in urban areas (urban heat island effect). Furthermore, it can affect the health conditions of several people due to overheating, primarily affecting the vulnerable societal groups (e.g., elderly, children, sick people) (National Weather Service, n.d.). Therefore, it is essential to address such significant climate impacts immediately and act to adapt to climate change challenges.

a) Existing climate services

In the case study site of North-east Brabant, climate adaptation is generally associated with sea-level rise, extreme precipitation, and flooding. However, in this region, water scarcity, drought, changed water quality also has an impact on agriculture and urban development too. A recent example of this took place during the summer of 2016 when rainfall and brimstones caused more than 20 million euros in damage. Therefore, to face these challenges, the Province of North Brabant and other regional stakeholders are collaborating to form a joint adaptation agenda.

Climate service such as the Climate Adaptation Service (CAS) is developing a knowledge portal in cooperation with regional actors such as Waterschappen (Regional water authorities), GGD (Public health department), and municipalities, as well as specialized research institutes (EVOKED, *Deliverable.3.2 NB v2*, 2019). The Province has recently developed a climate knowledge portal that serves as a guidance toolkit and includes information on the instruments, and best practices for climate change adaptation in regard to all the end-users and decision-makers in the region (EVOKED, *Deliverable.3.2 NB v2*, 2019). This climate service also focuses on the farmers as they own a lot of land. This information was also confirmed by the interviewee who was interviewed during this research for the North Brabant case study site.

During the interview, the interviewee also mentioned that climate services should not only provide knowledge and information about climate change, its consequences and how to deal with it but also include subsidy programs for people (help people with money) to adapt better. The climate service (climate knowledge portal) also provides information on action plans, instruments, story maps (acts as a guide and has real-life past experience), subsidy programs, policies, and international laws (through stress-test approach) in regard to climate adaptation measures. The interviewee also stated that more tools like this must be introduced and promoted, and this can help in reducing the usability gap.

Furthermore, according to the respondents of the survey, the service does not include any disaster risk assessment framework or evacuation procedure as there are other existing services that provide this information in the safety and protection sectors.

During a workshop of EVOKED, information was gathered from the relevant project partners with respect to the North Brabant Case study. This information was further analyzed and condensed to reflect relevant information pertaining to the existing climate services in

North Brabant. Table 6 shows the existing climate services in the region of North Brabant, the focus of the climate service, the various climate impacts in the North Brabant region, involved stakeholders, and the way these climate services are represented.

LOCATION	**CLIMATE IMPACTS IN THE REGION**	**INVOLVED STAKEHOLDERS (Relevant climate impacts-Perception)**	**EXISTING CLIMATE SERVICES**	**FOCUS OF CLIMATE SERVICES-CLIMATE IMPACTS**	**INFORMATION PROVIDED BY THE CLIMATE SERVICES**	**REPRESENTATION OF THE CLIMATE SERVICES**
The Netherlands-North Brabant	Extreme precipitation, fluvial and pluvial flooding, heat stress and droughts	Municipalities in the AS50-region (Extreme precipitation, fluvial flooding, heat stress, and droughts)	Klimateffectatlas North Brabant	Extreme precipitation, fluvial and pluvial flooding, heat stress and droughts (effect on agriculture) - Stresstest approach	Extreme precipitation, pluvial flooding, heat stress, droughts and NAS sector (time scale, water shortage percentage of green spaces, vulnerable urban area)	Map with guiding text meta information
The Netherlands-North Brabant		Water Board Aa & Maas (Extreme precipitation, fluvial flooding, and droughts)	Regional Climate Portal		Extreme precipitation, fluvial and pluvial flooding, heat stress and droughts	Story map, images, and infographics

The Netherlands-North Brabant		Province of North Brabant (Extreme precipitation, fluvial flooding, and droughts)	Stress Test light AGRIFOOD Capital		Extreme precipitation, fluvial flooding, changed water quality, heat stress and droughts 11 (water depths, groundwater level, vulnerable objects and areas, location of flood defenses, natural areas, water extraction sites, time scales)	A report including maps, graphs, and images

Table 6. Overview of North Brabant's existing climate services analysis

In addition to the document analysis, interviews, and workshops, the existence of the 3 climate services (Klimateffectatlas North Brabant, Regional Climate Portal, and Stress-Test light AGRIFOOD Capital) was also verified by conducting a survey with six stakeholders linked to the North-Brabant case study site.

b) Usability Gap

From table 6, it can be observed that the existing climate services addresses all the climate impacts in this region and focuses on urban and agricultural sectors. However, it is seen that only the water board, municipality, and the Province are the involved stakeholders in this case. According to me, private business, landowners, citizens, construction developers, etc. should also be involved to use these climate services. Thus, there is a need for collaboration and integration of different departments/sectors for making informed decisions from climate adaptation measures.

According to the document analysis, on a regional scale, there is no lack of information or data. However, the accessibility and applicability of the knowledge provided by the climate services is an issue. Additionally, climate adaptation measures are not adequately incorporated in urban planning and development. Moreover, the general public still doesn't perceive river floods as a risk because the protection as of now works well. However, there is a possibility of urban floods and droughts in the future. Only the people who have experienced these events in the past are aware, and the others are still not. In certain area-specific measures have been taken by the involved actors. However, a structural and integrated approach is still lacking.

Moreover, during the interview, when the interviewee was asked, to what extent the climate services are being used or not, the interviewee replied by saying that the necessary instruments are being used quite well by professionals related to climate change adaptation (Municipality, planners, water board, researchers, etc.) however, the general public and companies might not be aware of this climate service and thus, needs more promotion. The interviewee also stated that there aren't any climate services that are tailored for a specific municipality at a local level. Instead, it is a broad forum of service on a regional level for all the municipalities. Additionally, the interviewee also mentioned that there is a potential usability gap that is seen, and this may be occurring due to a lack of awareness and the visual representation of the information. This information was also verified by the survey respondents, however, the stakeholders from the survey also specified some other potential factors influencing the usability of a climate service, such as behavioral issue/ Participatory issues, governance issues at different levels, lack of taking responsibility, lack of political willingness, lack of coordination or collaboration, lack of resources (finance, time, technology etc.), communication issues, lack of awareness, lack of relevant and adequate information, lack of information on adaptation measures (solutions) and lack of stakeholder's information needs).

Thus, it is essential to understand the stakeholder's demands and information needs first to develop the climate service, which will tailor to the stakeholders that are responsible to make informed decisions and implement climate adaptation measures (EVOKED, *Deliverable.3.2 NB v2*, 2019). It is also essential to make these climate services more user-friendly, attractive with visualization or interactive maps, as well as the right information (EVOKED, *Deliverable.3.2 NB v2*, 2019). Such improvements in the climate services will not

only reduce the usability gap but also raise awareness and educate more people about climate change and its risks, which will increase active participation and involvement in building a safe and sustainable environment. Concrete measures need to be taken such as information on cost and adaptation measures, a timeline for implementing measures, raising awareness, integrated approach (urban planning and development), analyzing hazard/risk maps (heat stress, floods, droughts, etc.), information on best adaptation and mitigation measures as well as increasing the level of management, collaboration, and coordination among different levels of governance or decision-makers.

c) Factors influencing the usability of climate services

i) Target Audience:

Document Analysis: Based on the North Brabant case study documents, it was observed that the critical stakeholders involved in making informed decisions and implement climate adaptation policies, spatial planning adaptation strategies, as well as measures, are the National government, Province Noord-Brabant, Provinciale bestuurders politieke partijen (Provincial administrators of political parties), Waterschappen - Regional water authorities (Aa en Maas, Brabantse Delta, De Dommel) and 64 municipalities (EVOKED, *Deliverable.3.2 NB v2*, 2019). However, climate services can be used by everyone. According to the documents it stated that the information provided in climate services must be tailored according to the stakeholders' demands to improve the usability of climate services.

Interview analysis: At the North Brabant region case study site, the interviewees specified that the target audiences for them are primarily the municipalities, planners, water boards, the province, and researchers. However, climate services are accessible to everyone. The interviewees also stated that, for a climate service to be useful to the end-users, it is essential that they are tailored according to the stakeholders' demands. Furthermore, the interviewee stated that there aren't any climate services that are tailored for a specific municipality at a local level; instead, there is a broad forum of service on a regional level for all the municipalities.

Survey analysis: All the six stakeholder respondents (both EVOKED partners and extended working groups) for the survey, stated that it is essential to tailor the information provided in a climate service according to stakeholder demands.

ii) Information goal / purpose and Framing:

Document Analysis: Based on this case study documents, it was analysed that the stakeholders' demands are primarily focused on the information based on climate adaptation measures and that the goal of the climate service must be essential for raising more awareness, educating people about climate change, promoting proactive behavior and implementing the best climate adaptation or mitigation practices. Furthermore, according to the documents, the information provided in the services must be easy to understand and accessible to everyone. The documents also specified that climate services must be like a guidance tool kit with instruments, relevant climate-related information, and best practices for climate adaptation for all end-users and decision-makers in the region.

Interview analysis: According to the interviewee, information framing in climate services must be easy to understand and perceive by the end-users. They also stated that the information must be scientific but not too technical for the end-users. The information must also be user-friendly for the end-users. Moreover, the interviewees feel that the information goal of a climate service must be mainly for raising more awareness, educating people about climate change, promoting proactive behavior, and implementing the best practice for climate adaptation or mitigation in the region.

Survey analysis: Similar responses were obtained in the survey stating that the information goal must be about raising awareness and educating others about climate change impacts and how to deal with these challenges better. The information framing, according to all six participants, was that it should be readable, easily understood, and user-friendly.

iii) DESTEP Model (Type of Information):

Document Analysis: According to the document analysis of North Brabant, it was observed that there was nothing mentioned about the type of information such as demographic, social, economic, political, ecological, and technological information aspects.

Interview analysis: However, according to the interviewee, the information on social, economic, and technological aspects are more crucial than compared to the others. The interview stated that they are trying to include these aspects in the existing climate services as well as developing services based on the needs of the stakeholders. It was also observed that the recently developed services consist of information on action plans, instruments (technology), story maps (acts as a guide and has real-life past experience- environmental),

subsidy(socio-economic), policies and international laws (politics) in regard to climate adaptation measures. Only the demographic information may not be as crucial as others, according to the interviewee.

Survey analysis: Only two survey respondents stated that the DESTEP model information is essential in a climate service. They also stated that depending on the stakeholder demands, the climate service should provide this type of information (DESTEP). However, the respondents did not specify which of these DESTEP information plays an important role in reducing the usability gap between the climate services and the end-users.

iv) Spatial/ Temporal information(action-oriented):

Document Analysis: Based on the document analysis of the North Brabant case study, it was observed that only the information on climate adaptation measures or mitigation measures under the spatial/temporal factors are essential in this case. There was no mention of the risk assessment framework or evacuation procedures in the documents.

Interview analysis: Similar results were obtained during the interview, as the interviewees felt the need to include information on the best climate adaptation practices that could be implemented in the region of North Brabant. As per the interviewee, there is no need to include information on climate risk assessment frameworks or evacuation procedures in the developing climate services as there are existing climate services in the safety and protection sector which provide information on Spatial/temporal aspects.

Survey analysis: However, during the analysis of the survey, none of the participants responded to the spatial/temporal aspect as a factor that could influence the usability of climate service. The respondents did not feel the need to include this information in the climate services as there could be other specific services/ tools that tailor to this information.

v) Communication Channel:

Document Analysis: According to the document analysis, it was observed that most of the climate services have one-way communication, which potentially causes the usability gap. Thus, having a two-way communication is essential to reduce the potential gap, as it includes workshops, field-trials, interviews (with relevant stakeholders), feedback loops along with the services, and online surveys while developing the climate services to understand the stakeholder's needs.

Interview analysis: The interviewee also stated that two-way communication is essential while developing a climate service that includes a feedback loop (workshops, interviews, surveys, and field trials) in order to monitor and improve the climate service. However, most of the services do not include a feedback section at the end, as it needs continuous monitoring and evaluation. Furthermore, it was also stated that there is a need to develop more communication tools. The interviewee also stated that initiating risk dialogues and exchanging knowledge will help in increasing awareness and active participation of stakeholders to make informed decisions.

Survey analysis: All the respondents stated that two-way communication is much more effective than a one-way communication system. Furthermore, they also stated that there is a lack of communication in the existing services, which needs immediate attention and improvement to avoid the usability gap.

vi) Representation:

Document Analysis: During the document analysis, it was found that there is a lack of visual representation (maps, 3D models, infographics, story maps, graphs, etc.) in the existing climate services based on the stakeholders' viewpoint. Most of the stakeholders felt the need to have climate services that are visually attractive, user- friendly, and readable. It was also observed from the documents that climate services with texts and graphics are more widely used by the end-users, as it attracts them and also helps them understand the information better. Thus, the documents suggested that the representation of the information in climate services is an essential factor which can influence the usability of a climate service.

Interview analysis: The interviewees suggested that the usability gap can exist due to the lack of adequate visual representation. According to the interviewee, it is essential to have an attractive representation like pictures and maps or 3D- models, but also the information must be relevant, readable, easy to understand, user-friendly, and must also tailor to the stakeholder's demands. It should also be easy to share the necessary information through YouTube videos, social media platforms, newsletters, etc. to raise awareness. And depending on the audience, it could be practical information or technical/scientific information.

Survey analysis: Similar results were obtained from the survey, as all the respondents stated that there is a lack of visual representation in the climate services and that there is a need to have better visualization and readability of the information provided in the climate service.

d) Summary: Overall, for the case of the North Brabant region, there is a need for adequate and relevant information for the climate services primarily for the municipality at a local level rather than having broad services for all the municipalities on a regional level. Climate services should mainly consist of information tailored to the stakeholders' demands. Thus, tailoring the climate service according to a specific group of audience is essential. The information goal of the service must be primarily to raise awareness, promote proactive behaviors, information on climate impacts, and how it can be tackled, and lastly, the ways to implement climate adaptation measures.

Furthermore, readability, better visual representation, information that is easy to understand, two-way communication, information on adaptation measures/climate risk assessments and raising awareness among the locals are some of the factors that need to be implemented while developing a climate service to reduce the usability gap between the climate services and the end-users. These factors mentioned above are also according to the stakeholders' needs. There is also a need to develop more climate services and communication tools which provide adequate information to the specific target audiences.

According to the researchers and the stakeholders, including most of the factors of the DESTEP model is essential in terms of the type of information, such as political, social, economic, technological, and environmental aspects of a climate service. This type of information will further benefit the stakeholders in understanding, planning and managing steps of the decision-making process. Furthermore, there was no emphasis on the spatial/temporal factors except the information on adaptation measures, which must be included in the climate service.

During the interviews and the survey, it was analyzed that the interviewees and the respondents also stated a few other potential factors that could cause the usability gap between the climate services and the end-users. External factors such as behavioral issues/ participatory issues, governance issues at different levels, lack of taking responsibility, lack of political willingness, lack of resources (finance, time, technology, etc.), and lack of awareness were mentioned while conducting this research by the practitioners and the stakeholders.

4.1.5. Drenthe- Fluvius region, The Netherlands case study

The Fluvius region consists of the higher eastern region of Hoogeveen, Midden Drenthe, the slopes of Westerveld, De Wolden, and the lower western part of

Steenwijkerland and Meppel (Klimaateffectatlas, n.d.). The Hondsrug (Dutch ridge of sand) runs through the middle of Drenthe. Furthermore, there are no watercourses running through this region; however, there are few canals such as the Hoogeveensche Vaart and the Oude Vaart (Klimaateffectatlas, n.d.). Table 7 shows the area for each region and the population.

Municipality	**Area**	**Population**
De Wolden	224,77 km^2 land 1,58 km^2 water	23.789
Hoogeveen	127,67 km^2 land 1,58 km^2 water	55.252
Meppel	55,69 km^2 land 1,34 km^2 water	33.155
Midden-Drenthe	341,01 km^2 land 4,86 km^2 water	33.311
Steenwijkerland	321,59 km^2 land 31,43 km^2 water	43.513
Westerveld	278,74 km^2 land 3,93 km^2 water	19.069
Total	**1369,41 km^2 land 44.72 km^2 water**	**208089**

Table 7. Location area and the population of each city in the Fluvius region (Klimaateffectatlas., n.d.)

Fig.14 shows the geographical location of the Fluvius region- Drenthe, The Netherlands.

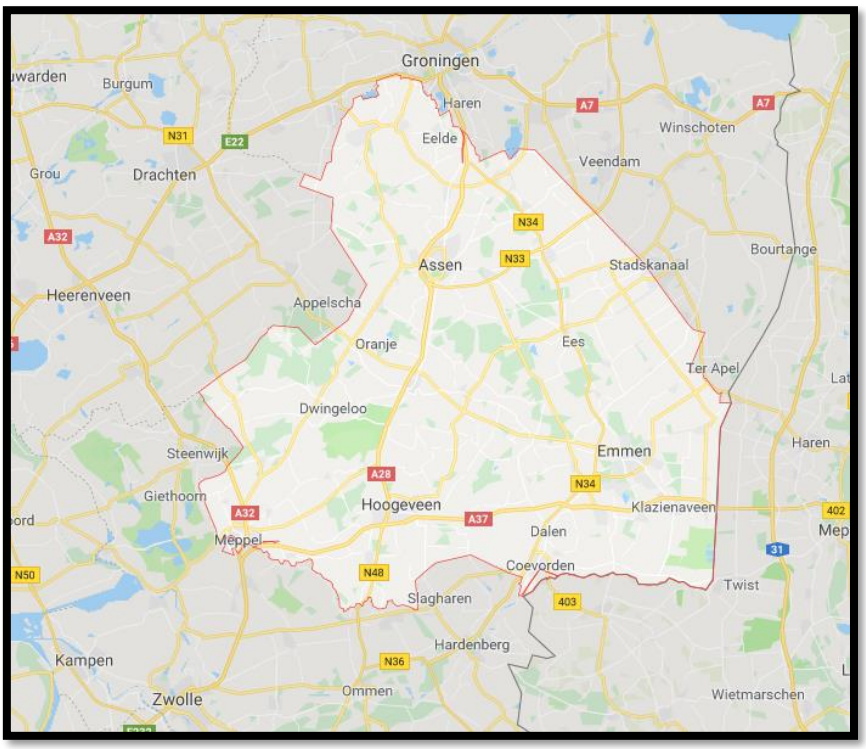

Fig 14. The geographical location of the Fluvius region (Drenthe), The Netherlands (Google maps, 2019)

The Fluvius region of Drenthe is still struggling to be more sustainable and resilient (Klimaateffectatlas, n.d.). Challenges like the heat stress, extreme precipitation in the urban areas, droughts in the rural areas, issues with the shared sewage systems, pluvial and fluvial flooding in Meppel due to its location (near the junction of the Drenthe Hoofd and Hoogeveensche canals and the Reest River, which empty into the Meppelerdiep before it flows into the IJsselmeer (Lake IJssel)) are still some of the climate change-related concerns that need to be tackled immediately as it is a risk to the society (EVOKED, *Needs and vision-Fluvius region*, 2018; *The Editors of Encyclopaedia Britannica,* 2013). According to the interviewees, the climate impacts in the aforementioned region are extreme precipitation, sea, and river level rise, which cause flooding in both urban and rural areas as well as frequent occurrence of droughts in the past few years.

a) Existing climate services

The Fluvius region in the North-Eastern part of The Netherlands, where the rivers IJssel and Vecht flow into the Ijssel lake, as mentioned before, possess a threat of flooding. Due to this, the regional and local governments are aiming to provide a water-safe area (water robust and climate-proof region) by 2100 where living, working, recreation, and entrepreneurship can prosper in terms of social and economic development. They also aim to increase

awareness among the communities about the effects of climate change through communication, active participation in the development of coping strategies, exchanging knowledge about responding better to floods or heat and enhance their resilience. The waterboard, therefore, plans to collaborate governments to shape the preparedness of communities at risk through effective communication strategies, connect different communities of different age groups, and initiate an exchange of knowledge and dialogues within these groups. The Drenthe Overijssel- Fluvius region aims to have the vision to create a climate-resilient community by introducing climate adaptation policies and initiating the stakeholders to implement them and make informed decisions, reduce the consequences of climate change for the citizens, and shift towards renewable energy.

The municipalities, provinces, and water boards are the primary stakeholders responsible for tackling the issues from the policy and analytical point of view (EVOKED, *Needs, and vision- Fluvius region*, 2018). At the national level, the ministries also get involved in spatial adaptation ("Fluvius | Platform water Regio Reest en Wieden," 2016). At the moment, within municipality departments, there are several groups that don't work well together with one another when it comes to integrating sectors together into one plan ("Fluvius | Platform water Regio Reest en Wieden," 2016). For this region, the major stakeholders responsible for developing climate adaptation policies and implementing measures are the Municipalities, water board of Drents Overijsselse Delta, province of Drenthe, citizens, businesses, housing associations, Ministry of Infrastructure and Water Management ("Fluvius | Platform water Regio Reest en Wieden," 2016).

According to the interviewees, they are in the process of developing new story maps as their climate service, which will be a part of the existing climate service-WDOD Klimaateffectatlas. The story map consists of stories of different departments (health, agriculture,food, water, and urban sectors) in their region that experienced the effects of climate change. The story map also consists of information or data in a schematic manner, which will be beneficial for making informed decisions by professionals on a governmental level (politicians, municipalities, provinces, and the water board), citizens, and private businesses. The information provided in these story maps will be specific to the target audience. Additionally, the visual representation of this story map is in the form of infographics, maps, pictures, texts, and videos. The goal of the story map is to raise

awareness, including information that is relevant to every stakeholder and using this information to make decisions and implement adaptation measures.

Furthermore, the respondent (researcher) from the survey stated that the existing climate services are being moderately used as there still might be some lack of information.

During a workshop of EVOKED, information was gathered from the relevant project partners with respect to the Fluvius region- Drenthe case study. This information was further analyzed and condensed to reflect relevant information pertaining to the existing climate services in the Fluvius region. Table 8 shows the existing climate services in this region (Drenthe- Fluvius region), the focus of the climate service, the various climate impacts in the region, involved stakeholders, and the way these climate services are represented.

LOCATION	**CLIMATE IMPACTS IN THE REGION**	**INVOLVED STAKEHOLDERS (Relevant climate impacts- Perception)**	**EXISTING CLIMATE SERVICES**	**FOCUS OF CLIMATE SERVICES- CLIMATE IMPACTS**	**INFORMATION PROVIDED BY THE CLIMATE SERVICES**	**REPRESENTATION OF THE CLIMATE SERVICES**
The Netherlands – DRENT	Fluvial flooding, Heat stress, droughts, NAS sector	Municipality of Fluvius region (Extreme precipitation, heat stress, drought, fluvial flooding)	National Klimateffectatlas	Extreme precipitation, heat stress, drought, fluvial and pluvial flooding (effect on agriculture) – Stress-test approach	Extreme precipitation, heat stress, drought, fluvial flooding, forest fire, and soil saturation, stress- risk management (percentage of hardened surface/ surface water, water depths, groundwater level)	Map with guiding text meta information

The Netherlands – DRENT		Water Board Drent Overijsselse Delta (Extreme precipitation, drought, fluvial flooding)	WDOD Klimateffectatlas		Extreme precipitation, heat stress and high temperature (water depths, flow paths, and road accessibility)	Map with guiding text meta information
		Province of Drenthe/Overijssel (Extreme precipitation, drought, fluvial flooding)				
		Safety region Drenthe/ Overijssel (Extreme precipitation, heat stress, drought, fluvial flooding)				

Table 8. Overview of the *Fluvius region's* existing climate services analysis

In addition to the document analysis, interviews, and workshops, the existence of the 2 climate services (National Klimateffectatlas and WDOD Klimateffectatlas) was also verified by conducting a survey with one researcher linked to the Fluvius region case study site.

b) Usability Gap

As observed in Table 8, the existing climate services address all the climate impacts in this region and focus on water, urban, and agricultural sectors. In this case, a variety of stakeholders are also involved, which helps in reducing the usability gap. However, the issue, in this case, is that awareness of the climate services, collaboration among different stakeholders, accessibility, and applicability of the knowledge is lacking, even though there is an abundance of climate services with relevant information. Thus, there is a need for

collaboration and integration of different departments/sectors for making informed decisions from climate adaptation measures. Due to these barriers efforts are being made by developing new climate services targeting all different sectors, as mentioned above.

Even though some of the development and adaptation practices are applied, it is still not under control as it could be seen during the 2018 droughts ("Fluvius | Platform water Regio Reest en Wieden," 2016). There is a gap within the system, taking responsibility, understanding the level of risk and the right measures that need to be applied, are still missing (EVOKED, *Needs and vision- Fluvius region*, 2018). Another important aspect is that the awareness among the citizens is often limited and are not able to link it with the experiences in the past such as the fluvial flooding (1998 in Meppel is seen as an important one in the region), pluvial flooding (especially in the urban areas of Hoogeveen) and droughts ("Fluvius | Platform water Regio Reest en Wieden", 2016). Thus, due to lack of awareness and linking it to the experiences. Most of the citizens are not able to understand the intensity of these climate impacts and the measures they can implement to adapt to climate change (EVOKED, *Needs, and vision- Fluvius region*, 2018). Additionally, the integration of all the municipalities and the water board is not on the same level or time (EVOKED, *Needs, and vision- Fluvius region*, 2018). There are also many conflicts of interest. Other challenges are the financial capacity, awareness, linking past experiences to risks, behavioral change or the urgency to act now, lack of responsibility, lack of perception in regard to climate change and the risks, lack of communication and coordination are still some issues that need attention now, in order to have informed decision-making process and implementation of climate adaptation measures (EVOKED, *Needs and vision- Fluvius region*, 2018).

Furthermore, climate adaptation measures are not fully incorporated within their approach in urban flooding and heat stress; thus, it still poses a threat. The risk from climate change impacts is perceived in a general way, which must be managed or accepted in a standard procedure or below a certain level due to cost-effectiveness, land use, etc. Only the people who have experienced these events in the past are aware, and the others are still not. Furthermore, due to broad and abstract visions and lack of clear guidelines, it becomes difficult to take action towards it. However, governmental stakeholders are more aware of the risk and are now trying to adapt to them ("Fluvius | Platform water Regio Reest en Wieden," 2016). There needs to be more collaboration between different stakeholders, raise awareness and knowledge among citizens (their role in tackling climate change and how they

can adapt to it), take concrete measures, collective narratives, increase trust and acceptance as well as introduce standard procedures.

During the interview, both the interviewees agreed that the existing climate services are not being used effectively based on the workshops and interviews with the stakeholders, which they had conducted. However, the respondent mentioned that climate services are being used moderately. The interviewees also felt that there is a need for more cooperation, educating and raising awareness among the stakeholders (especially the municipalities and provinces) is necessary to reduce the usability gap of the climate service. According to the interviewees, the information provided in a climate service must be tailored according to the stakeholder's demands at both national and regional levels so that the end-users can relate to their own projects and make use of the information provided. Similar views were obtained by the respondent of the survey stating that the usability gap can be caused if the information is not tailored to the stakeholder's demands, and this can affect the decision-making process negatively in both the understanding and planning phase.

c) Factors influencing the usability of climate services

i) Target Audience:

Document Analysis: Based on the Drenthe- Fluvius region case study documents, it was analyzed that the information provided in climate services must be tailored according to the stakeholders' demands based on a specific target group/ audience. However, there was no mention in the documents about the target audience being a factor for the usability gap.

Interview analysis: At the Drenthe- Fluvius region case study site, the interviewees specified that the target audiences for them are primarily professionals on a governmental level (politicians, municipalities, provinces, and the water board), citizens, and private businesses. The interviewees also stated that the information must be tailored to the stakeholders' demands at both national and regional levels so that the end-users can relate to their own projects and make informed decisions to tackle climate change.

Survey analysis: After analyzing the data received from one survey respondent (researcher), it was observed that the usability gap could be caused if the information is not tailored to the stakeholder's demands, and this can affect the decision-making process negatively in both understanding and planning phase.

ii) Information goal / purpose and Framing:

Document Analysis: Based on the Drenthe- Fluvius region case study documents, it was observed that the goal of the climate service is to increase awareness among the communities about the effects of climate change through communication, active participation in the development of coping strategies, exchanging knowledge about responding better to floods or heat and enhance their resilience. However, there was no mention of the information framing of the climate services in the documents.

Interview analysis: According to the interviewees, information framing in climate services must be easy to understand and perceive by the end-users and must also be easily accessible to everyone. The interviewees stated that the goal of the information provided in the climate service must be based on raising awareness and providing relevant information to every stakeholder so that they can use this information to make informed decisions and implement suitable adaptation measures.

Survey analysis: However, the respondent did not state anything about the information goal or the information framing as a factor that could influence the usability of a climate service.

iii) DESTEP Model (Type of Information):

Document Analysis: According to the document analysis of the Drenthe-Fluvius region case study site, it was observed that there was no mention of the DESTEP - type of information as a factor influencing the usability of climate services.

Interview analysis: According to the interviewees, the information on social, economic, demographic, political, ecological, and technological aspects were not that important to include in the new climate services. The interviewees felt that these types of information could be obtained from other sources, which is why the interviewees will not be including any of these DESTEP factors in their climate services.

Survey analysis: However, the survey respondent stated that the usability gap between the climate services and the end-users could be caused due to the lack of relevant information such as the DESTEP model, and according to the respondent, this information is essential to reduce the usability gap.

iv) Spatial/ Temporal information(action-oriented):

Document Analysis: Based on the document analysis of the Flensburg case study, it was observed that the spatial/temporal factors such as risk assessment framework and evacuation procedures were not mentioned in the documents. However, information on climate adaptation measures is considered to be essential in a climate service according to the documents analyzed, as climate adaptation measures are not fully incorporated within their approach in urban flooding and heat stress, which poses a huge risk for the society.

Interview analysis: Similar results were obtained during the interview, as the interviewees did not feel the need to include information on risk assessment frameworks, evacuation procedures, or mitigation measures. The interviewees only felt the need to include information on climate adaptation measures in climate services.

Survey analysis: However, during the analysis of the survey, the respondent did not respond to any of the spatial/temporal aspects as a factor that could influence the usability of climate service.

v) Communication Channel:

Document Analysis: According to the document analysis, two-way communication is more beneficial to reduce the potential usability gap, as it includes workshops, field-trials, interviews (with relevant stakeholders), feedback loops along with the services, and online surveys while developing the climate services to understand the stakeholder's needs.

Interview analysis: According to interview analysis, both the interviewees stated that incorporating a two-way communication is also essential to improve the usability gap as it will help in monitoring the climate service, evaluate it and thus, improve it for the future. Thus. the interviewees mentioned that they are incorporating workshops, interviews, field trials, stress-test, and risk dialogues to initiate the two-way communication while developing the story map (climate service), which will, in turn, help in understanding the information needs of the end-users.

Survey analysis: The respondent stated that two-way communication is much more effective than a one-way communication system. Furthermore, they also stated that there is a lack of communication in the existing services, which needs immediate attention and improvement to avoid the usability gap.

vi) Representation:

Document Analysis: During the document analysis, it was found that stakeholders felt the need to have climate services that are visually attractive and readable. However, this factor was not emphasized throughout the documents of the Drenthe- Fluvius region case study site.

Interview analysis: However, both the interviewees suggested that the usability gap can exist due to the lack of adequate visual representation. They also mentioned that the visual representation of the story map (new climate service under development) would be in the form of infographics, maps, pictures, texts, and even videos. According to the interviewees, the representation of the climate services is more relevant than the information so that the end-users are attracted to use it but of course, in addition to this, the information must be relevant, fit the level of scale, and should be tailored according to the stakeholder's demands.

Survey analysis: Similar results were obtained from the survey, as the respondent stated that there is a lack of visual representation in the climate services and that there is a need to have a better visualization of the information provided in the climate service.

d) Summary: Overall, for the case of Drenthe-Fluvius region, there is a need for adequate and relevant information provided in climate services which must be tailored according to the stakeholder's demands at both national and regional level, so that the end-users can relate to their own projects and make informed decisions to tackle climate change. Climate adaptation measures (spatial/temporal factors) are not fully incorporated within their approach in urban flooding and heat stress, and it poses a considerable risk for society. Thus, more climate services must be developed to raise awareness about climate change impacts, and knowledge must be transferred on how to adapt to climate change as an essential aspect of the information goal/ purpose of the climate services.In terms of spatial/ temporal factors, climate services must include information on implementing climate adaptation measures.

According to the result analysis, it was observed that there was no emphasis on the DESTEP model as a factor influencing the usability of climate services. Furthermore, in order to bridge the gap, the decisions must be more concrete, develop trust and acceptance among the stakeholders as well as the inhabitants, and promote proactive actions. Better visual representation, information that is easy to understand, two-way communication, information

based on stakeholders needs and that fits the level of scale and introducing risk-dialogues are some of the other essential aspects that can be implemented and improved in order to reduce the usability gap between the end-users and the climate services. The interviewees and the respondents also stated a few other potential factors that could cause the usability gap between the climate services and the end-users. External factors such as behavioral issues/ participatory issues, governance issues at different levels, lack of taking responsibility, lack of political willingness, lack of resources (finance, time, technology, etc.), and lack of awareness were mentioned while conducting this research by the practitioners and the stakeholders.

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion and case study comparison

The main focus of my research was to explore and understand which factors influence the usability of a climate service in relation to all the selected case study sites. Understanding these factors and then making improvements in them would help in developing new climate services, which will potentially be used by the end-users effectively. By doing so, the usability gap between the end-users and the climate services may be reduced, and informed decisions can be made to implement suitable climate adaptation measures.

To answer the main research question (Which factors explain why climate adaptation services are (not) being used by end-users to develop adaptation plans, and how could the usability of these services potentially be improved if needed?), first, theoretical research was conducted. Through this theoretical research, six factors that could potentially influence the usability gap between a climate service and the end-users were derived, as stated in the conceptual model (Fig. 7). Following this, a case study strategy was conducted, where five case study sites in Europe were selected. The case study sites were based on the characteristics of their location, climate impacts, spatial planning strategies, governance, and policies, as well as if these case study sites have existing climate services.

The first two sub-questions, regarding the existing climate adaptation services and the relevant stakeholders at the case study sites, were answered by conducting desk research (existing Documents of project EVOKED), workshop findings, interviews and surveys with relevant stakeholders and researchers from each case study site. The list of existing climate services and the involved stakeholders can be found in chapter 4 (Result analysis) for each case study site, represented by Tables 3, 4, 5, 6, and 8. In most cases, the involved stakeholders are national government, regional government, municipalities, water boards, nature protection agencies, NGOs, private businesses, landowners, construction developers, farmers, and many more.

Furthermore, to answer the third sub-question, interviews and surveys were conducted to get in-depth knowledge about the extent to which the climate services are being used. In most cases except Flensburg, it was observed that climate services are being moderately used, but all the participants also stated that it was difficult to measure the usability of a climate service. However, in the case of Flensburg, it was observed that there

isn't enough information for climate adaptation measures at a local level, and thus, it was assumed that the climate services were not used that effect due to the lack of information at a local level.

To answer the fourth sub-question, secondary research (literature review and existing EVOKED documents) was conducted. Through this method, six factors were derived, and based on this, a conceptual model (Fig. 7) was developed depicting the potential factors influencing the usability of climate services. The results of this secondary research were also verified by conducting primary research (interviews and surveys) with relevant stakeholders and researchers/practitioners from each case study site. Based on all the literature reviews, theories, document analysis, workshops, interviews, and surveys, it can be said that all the six factors mentioned do play an essential role in terms of the climate services usability as they are all interlinked with each other.

The five case study sites were compared side by side to understand how the influencing factors vary according to the different challenges of a particular case study site. Based on a comparison for all the case study sites, it was mentioned that raising awareness was one of the common factors for the usability gap. Exchanging knowledge among governmental actors as well as citizens in regard to climate change and its impacts was essential to achieve every case study's goal. Another factor common to all these cases was collective narrative and examples of good projects to make the area sustainable and climate-resilient. These are a few of the most common factors that need to be improved to reduce the usability gap between climate services and the end-users.

According to most of the respondents, relevant information based on the stakeholder's demands as well as the visual representation (maps, 3D-models, graphs, infographics, videos, story maps, pictures, etc.) of the information provided in the climate services is the two most essential factors for usability gap. In addition to that, most of the participants felt that the information must be readable, user-friendly, easy to understand, and not very scientific/technical, which comes under the information framing factor. Moreover, the information goal and purpose must be specific (raising awareness, changing cultural and social norms, initiating climate adaptation measures, and increasing social engagement), depending on the target audiences such as professionals (architects, researchers, etc.). The information goal/purpose could also be about how to cope with the effects of climate change, climate adaptation measures, what are the climate impacts in the region.

Table 9 shows a schematic description of how each factor influences the usability of climate services. Furthermore, there are a few other factors as well that were discovered while conducting this research and are as important as the other six factors mentioned, which influence the usability of the climate service. Therefore, Table 9 will represent a comparison of all the case study sites and whether the factors influence the usability of the climate service of respective case study sites.

FACTORS	LARVIK	ARVIKA	FLENSBURG	NORTH-EAST BRABANT	DRENTHE (FLUVIUS REGION)
1- Target audience	Partially Influences	Influences	Influences	Influences	Influences
2- Information goal/purpose	Influences	Influences	Influences	Influences	Influences
3- DESTEP model information	Partially influences (only economic aspect)	Partially influences (only social, economic and environmental aspects)	Partially influences (only social, economic, demographic and environmental aspects)	Partially influences (only social, economic, political, technological and environmental aspects)	Does not influence
4- Spatial/Temporal information	Partially influences (only adaptation measures)	Partially influences (only adaptation measures)	Partially influences (only climate risk assessment and adaptation measures)	Partially influences (only adaptation measures)	Partially influences (only adaptation measures)
5- Communication channel	Influences	Influences	Influences	Influences	Influences
6- Representation of information	Influences	Influences	Influences	Influences	Influences

7- Other factors (political willingness, behavior/participation, responsibility, lack of resources, lack of awareness and exchange of knowledge, governance, coordination, and collaboration among stakeholders)	Influences	Influences	Influences	Influences	Influences

Table 9. Overview of potential factors influencing the usability gap between the end-users and climate services based on factors testing (cross-comparison of case study sites), Source: Author

Overall, the above information gained from the document analysis, interviews, and surveys also verify the theories of Moser's (2010) modes of communication and communication needs for climate services to improve usability. Two-way communication is essential while developing any climate service. Furthermore, all the information must be tailored according to the stakeholder's demands based on the analysis of all the cases. It was also noticed that almost all the case study partners did not emphasize on the DESTEP model of information. However, the DESTEP model is an integral part of the type of information that helps in strategic planning and the decision-making process (Vliegar, 2012). Raaphorst's theory of climate information design, assisted as a guidance framework to evaluate all the potential factors influencing the usability gap in the existing climate services. In terms of spatial and temporal factors, none of the case study sites include evacuation procedures. Except for Flensburg, no other case study sites include risk assessment frameworks in their climate services that are currently being developed. However, every single one of them has information about climate adaptation measures. In addition to this, most of the respondents from the survey and interviews stated that the usability gap influences the decision-making process in the understanding and planning phase and not the managing /implementation phase. However, as stated in the theory of Moser and Ekstrom (2010), the managing phase is the final stage where adaptation measures are implemented, and if there is a usability gap, then the decision will not reach this stage at all. This analysis can be only evaluated by a feedback loop (Moser and Ekstrom, 2010).

To summarize, the following are the explanation of how these six factors influence the usability of climate services:

For the ***1st factor of the target audience***, it can be concluded that if the information is not specific for the specific end-users, according to stakeholder's demands and their information needs, then there will be a usability gap between the climate services and the end-users.

For ***the 2nd factor of information goal/ purpose***, it can be concluded that the information provided in the climate service must be clear about their goal/purpose (raise awareness, educate about climate impacts) for the relevant stakeholders to use and if the information framing is not flexible, not easily accessible, not user-friendly, too technical and not easy to understand or read then there will be a usability gap between the climate services and the end-users.

For the ***3rd factor of DESTEP model*** information, in theory, it has been recommended that if all these factors are not included in the climate services, then it may cause the usability gap between the climate services and the end-users. However, in practice, only certain aspects are used based on the stakeholder's demands and not all the 6 components of the DESTEP model (Demographic, economic, social, technological, political, and environmental). Hence, the focus should be given on practical use, which will help in reducing the usability gap of climate services.

Similarly, for the ***4th factor of spatial and temporal factors*** (action-oriented information), not all the 3 aspects (Risk assessment frameworks, evacuation procedure, and climate adaptation or mitigation measures) can be applied in one climate services in a practical sense. However, there must be several other climate services that fulfill these information needs. Hence, a single climate service does not need to have all these aspects together for reducing the usability gap.

For the ***5th factor of communication channel*** it can be concluded that having a feedback loop like field trials, workshops, interviews, surveys, comment boxes, etc. which is a two-way communication for the climate service is proven to be beneficial for all the cases, as the climate service can be monitored and evaluated which helps in improving the usability gap between the climate services and the end-users for all the cases as well as improving the climate services according to the stakeholder's demands/ information needs.

For the ***6th factor of representation of information***, it can be concluded that if the information is easy to understand, readable, user-friendly service and visually attractive (maps, pictures, graphs, infographics, 3d-models, etc.) for the end-users, then the usability gap will be reduced, as the stakeholders will be attracted to use the climate service.

Lastly, there are few ***other factors***, based on literature reviews, theories, interviews, workshops and surveys, it was observed that if there is a lack of political willingness, lack of behaviour change/participatory issue, governance issues at different levels, lack of resources (time, finance and technology), lack of taking responsibility, lack of awareness and exchange of knowledge, lack of collaboration or coordination among the decision-makers and end-users then there will be a usability gap in the climate services.

To answer the fifth sub-question, the usability gap between the climate adaptation service and the end-user can be improved by developing new climate services to tackle all the climate impacts at a particular case study site in such a way that it takes into consideration all the factors that affect the usability of a climate service. Developing new or improving existing relevant services will ensure that the case study site is prepared for all the climate change impacts.

By conducting the interviews, surveys and attending the workshop with the project partners of EVOKED (both researchers and stakeholders) from each case study site, it provided a clear understanding of the on-going project as well as the development of new climate services which will potentially reduce the usability gap for the existing climate services. Efforts are being made in these selected case study sites to develop new climate adaptation services based on the stakeholder's demand. Furthermore, during the development of the new climate services in each case study area, the project partners are initiating workshops, field trials, interviews, and surveys with the involved stakeholders and end-users of the climate services to understand their information needs. This also helps them to monitor and evaluate the climate services in order to improve the quality of the services as well as reduce the usability gap of the existing services. Thus, a two-way mode of communication is applied in all the case study areas.

The table 10 below represents an overview of the information on the developing climate services for each case study based on the interviews, surveys, and document analysis of EVOKED. The information was categorized based on the six factors (conceptual model, Fig 7).

INFORMATION ON THE DEVELOPING CLIMATE SERVICES	LARVIK	ARVIKA	FLENSBURG	NORTH-EAST BRABANT	DRENTHE (FLUVIUS REGION)
Types of climate services	Blue-green infrastructure template	Story maps	Story maps, climate impact assessment, socio-economic scenarios, flood maps	Climate knowledge portal (Story maps, action plans, instruments, subsidy programs, and policies)	Story maps
Target audience	Real-estate developers, municipality, politicians, builders, and landscape architects	Political leaders, municipalities, and planners	Regional and local level stakeholders, builders and architects and citizens	Politicians, municipalities, provinces, water board, citizens, private businesses, planners, researchers, Ngo's and farmers	Politicians, municipalities, provinces, water board, citizen and private businesses
Information goal/purpose	Cost-benefit analysis, action-oriented, and raise awareness	Climate impacts, action-oriented, and raise awareness	Re-designing the sea-side, implementing adaptation measures, improving the decision-making process, raise awareness	Raise awareness about climate change and its consequences, how to tackle climate change impacts and adapt better	Implementing adaptation measures, improving the decision-making process, raise awareness

DESTEP model information	Economic aspects	Economic, social and environmental aspects	Economic, social and environmental aspects	Environmental and social aspects	None
Spatial/Temporal information	Adaptation measures	Adaptation measures	Risk assessment frameworks and Adaptation measures	Adaptation measures	Adaptation measures
Communication channel	Two-way communication (workshops, interviews, surveys, dialogues and field trials)	Two-way communication (workshops, interviews, surveys, and field trials)	Two-way communication (workshops, interviews, surveys, and field trials)	Two-way communication (workshops, interviews, surveys, stress-tests, dialogues and field trials)	Two-way communication (workshops, interviews, surveys, stress-tests, dialogues and field trials)
Visual representation of information	Graphs, excel sheets and text information	Maps and texts	Maps, texts, pictures, and graphs	Videos, maps, texts	Infographics, maps, videos texts, 3D-models

Table 10. Overview of the information based on climate services that are being developed (cross-comparison), Source: Author

Furthermore, during the interview and survey analysis, it was observed that at all the case study sites, the following points improve the usability of the climate services in order to make informed decisions and implement adaptive climate measures for sustainable and resilient surroundings.

- Raising awareness among governmental and political parties as well as citizens and other private organizations.
- Exchanging dialogues and knowledge related to climate change.
- Taking responsibility when a natural disaster occurs.

- Need for active participation and behavioral change among the responsible stakeholders.
- Incorporating trust and acceptance among citizens to feel safe and secure in spite of the effects of climate change.
- Improving communication.
- Develop more concrete measures and integrated approaches.
- Building more collaboration and coordination among the involved stakeholders/ decision-makers related to climate change.

5.2. Recommendations:

The main recommendation for future academic research will be to further compare these cases in terms of their different spatial planning culture. As different countries in Europe have different policies, planning structures, governance, infrastructure management, etc. It would also be interesting to see how this spatial planning culture differs from place to place, depending on the climate impacts that they experience. Furthermore, a cross-comparison study, just like this researcher should be done of other cities in Europe as well, especially if the comparison is made within cities in eastern Europe and western Europe, as the usability factors may differ due to different climate impacts, governance structure, and spatial planning culture.

Additionally, future academic research could also be done with the citizens to see how they perceive the climate services and to what extent are they aware of it, or even to what extent do they make use of it. This could also focus on the communication needs model (Moser, 2010) and test if there is a usability gap between climate services and the citizens.

Since, this research shows the importance of information needs of stakeholders to reduce the usability gap between the end-users and the climate services, following are the recommendations which will also help in improving the decision-making process and implementing measures:

- More climate change experts should be involved in making the hazard/risk maps so that there is a scientific base of information as well.
- The visualization of climate services should be made attractive in order to involve more stakeholders or end-users.

- All the climate services should include a feedback loop at the end so that comments and suggestions can be recorded from the end-user's point of view and make changes to improve the service accordingly. This will help in monitoring and evaluating climate service in order to determine the usability of the service.
- Start dialogues with colleagues and stakeholders in every organization and develop concrete measures/ integrated approaches to create a safe and sustainable climate-adaptive environment. This will also help in determining the information needs for a climate service.
- To raise awareness about climate services and climate impacts in today's world, social media posts (Facebook, Twitter, Instagram, YouTube, etc.) will be more useful to reach and educate a wide variety of the population from different age groups about climate impacts, its consequences, how to deal with it and adapt to this in an effective and efficient manner.

5.3. Critical reflection

As a master student of Spatial planning- Cities, Water and climate change at the Radboud University, The Netherlands, I had an opportunity to conduct my master thesis on understanding the usability factors of climate services. Being a part of the EVOKED project at Deltares, The Netherlands (An Independent institute for applied research), I was able to understand the usability factors not only theoretically but also practically. The practical aspect was important because my goal for this research was to make it useful for the end-users so that they can make informed decisions for implementing adaptation measures.

In today's world, climate change is one of the essential aspects that we all have to face, and thus, it was exciting for me to begin my journey of conducting this research to find the factors that could influence the usability of climate services. This piqued my interest because I could help in improving these gaps, which in turn would benefit the society in terms of the decision-making process and implementation of climate adaptive measures.

To understand the usability factors, initially, a mixed research approach of both qualitative and quantitative analysis was chosen. However, due to time constraints and collecting a large amount of data from different stakeholders it was not feasible to conduct quantitative research. Simultaneously, I also received fewer than expected survey responses. In total 17 survey responses from all the case study sites were received, which also made me

realize that quantitative analysis would not be possible for this research. Thus, I chose to do qualitative research by using a case study strategy. In order to strengthen the thesis, different sources were selected to conduct the qualitative case study research. Such as collecting data from existing documents, interviews, workshops and surveys with relevant stakeholders and researchers. The language barrier was another issue for collecting data from all the potential stakeholders that are involved in all the case study sites. Even though the language was a barrier with the stakeholders, the necessary information was not compromised, as the interviews were always conducted in the presence of a researcher who was able to communicate in both English and the respective regional languages. To validate the findings of the interview, a survey questionnaire was also developed, targeting the relevant stakeholders, researchers, and similar working groups. This also allowed me to conduct this research in an inclusive way by including a considerate number of stakeholders and researchers and hence a large amount of data was collected for analysis.

During the interview, I did face some technical difficulties where I could not hear the respondents clearly. However, this was rectified by reconfirming with them via email and also conducting the survey with similar relevant stakeholders and researchers from each case study site. The interviewees were selected through purposive sampling so that the data collected is from relevant sources who are involved in developing climate services, improving existing services, and making informed decisions for implementing adaptation measures for each case study site. Furthermore, during the survey, snowball sampling was chosen to cover all the relevant stakeholders and researchers involved in this case on a larger scale. These experiences have better equipped me so that in future, I can deal with such challenges in an effective and professional manner.

By reviewing past literature, a theoretical framework/conceptual model was developed to answer the research question. From my findings, it was clear that most of the stakeholders and the researchers of each case study site felt that target audience, information goal/purpose and framing, representation, and two-way communication factors are highly essential to include in the climate service. Spatial/ temporal and DESTEP model information factors are also essential; however the findings show that not all the information aspects are essential to include in a climate service. However, it was also found that there are many other external factors as well that could influence the usability of climate service.

While collecting the data through interviews and surveys, the participants were highly motivated to provide any essential information for my thesis. They were also very focused on how to improve the usability gap between the climate services and the end-users, as well as how they could develop a new climate service that tailors to the stakeholders' needs.

According to me, quantitative analysis and reviewing policy documents for each case would have further strengthened the arguments in this research. However, due to time constraints, more focus was given to the practical knowledge as well as the data from the literature review, interviews, documents of EVOKED, and surveys from experts who have the same field of work as this research topic. Overall, I had a fantastic experience and gained a lot of knowledge while doing this research. It taught me aspects of time management, interpreting data, conducting interviews, transcribing the interviews, conducting online surveys and analyzing them, interacting with stakeholders and researchers from different countries, and working with them as well as writing a research thesis. I enjoyed every bit of my research process.

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7. LIST OF FIGURES AND TABLES

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Figure 1- Thesis outline, Source: Author

Figure 2.- Moser, S. & Ekstrom, J. (2010). A framework to diagnose barriers to climate change adaptation. *Proceedings of the National Academy of Sciences of the United States of America*. 107 (51), p. 22026-22031. http://dx.doi.org/10.1073/pnas.1007887107

Figure 3 & 4.- Moser, S. (2010). Communicating climate change: history, challenges, process, and future directions. *WIREs Climate Change*. 1 (1), p. 31-53. http://dx.doi.org/10.1002/wcc.11

Figure 5. - Vliet, V. (2010). DESTEP Analysis, a strategy, and marketing tool | ToolsHero. Retrieved from https://www.toolshero.com/marketing/destep-analysis

Figure 6. – Raaphorst. K. et al. (n.d.), EVOKED., R&D program., Climate information design

Figure 7.- Conceptual model (Influencing factors and determining the usability gap of the climate services among end-users, Edited by the author)

Figure 8.- Strategic map, Source: Author

Figure 9.- NGI, (2016) N. EVOKED. *R&D program.,* Retrieved on 8th March 2019, from https://www.ngi.no/eng/Projects/EVOKED

Figure 10.- The geographical location of the Larvik,Norway (Google maps, 2019)

Figure 11.- The geographical location of the Arvika, Sweden (Google maps, 2019)

Figure 12.- The geographical location of the Flensburg, Germany (Google maps, 2019)

Figure 13.- The geographical location of the North-East Brabant, The Netherlands (Google maps, 2019)

Figure 14.- The geographical location of the Drenthe-Fluvius region, The Netherland (Google maps, 2019)

Table references:

- **SURVEY LINK:**

Qualtrics software (SURVEY LINK) -
https://qtrial2019q2az1.az1.qualtrics.com/jfe/form/SV_eu1TW72LlcFp52Z

8. APPENDIX

APPENDIX 1: INTERVIEW GUIDELINE

Interview Guideline for EVOKED Project Partners

Introduction of the goal of the research and ask permission for recording the interview

Hello/ Good morning **(Respondent: Case Stakeholder and researcher)**,

First of all, I want to thank both of you for letting me do an interview, especially in such short notice, and thank you very much for your co-operation contributing to my research. Via our previous email correspondences and video workshops of EVOKED, we have already discussed the main topic of the research: Climate adaptation services and the factors influencing their usability **(Case study sites of EVOKED).** The main objective is to identify the usability gap, explain the factors causing the usability gap, and how this can be improved in the future, which will be a part of the recommendations.

Furthermore, I also want to inform you that information that is discussed during our conversation will only be used for academic purposes. Only a thematical description of your function and your organization will be used in my thesis to guarantee anonymity. Do you both agree to this? **(wait for the response from respondent)**

Finally, I also want to ask you if I can record our conversation in order to transcribe this interview afterward, which a crucial contribution to the Thesis. **(wait for the response from respondent)**
There will be a few questions that will be different for each of you– **practitioner** and **researcher**. I will mention it before I ask the question. However, most of the questions are going to be common for both. It will be great if you would also like to answer the questions of each other in case you have some additional information to add.

The interview would last for 45 mins to 1 hour, depending on your response. It is also possible to ask me to stop in case you have any doubts during the interview. Do you have any questions before we start? **(wait for the response from respondent)**

Then we can now start with the interview.

Background information about both the respondents

1. Could you please tell me something about the organization that you are in, as well as your position and your role?
2. How are you involved in this Project EVOKED? Did you have some background experience or interest in climate services?

Selected themes for the interview

Climate Impacts

1. What are the climate impacts that you find in your case study area?
2. Which climate impacts of your region are addressed in the existing climate services in your region?

Climate services

1. What is your perspective on climate services? - Case Stakeholders
2. What are the existing available climate services for your region?
3. According to you, to what extent are these services being used or not being used? And why is that so? = Both Project partners
4. What is the reason behind selecting only these climate services for your region for the Project EVOKED?
5. Are you developing any new climate services for the project EVOKED? If so, then could you explain what are you developing and why are you developing the climate service?

Identify the usability gap

1. According to you, what are the information needs of the involved stakeholders? And do these existing climate services fulfill their needs?
2. Do you think there is a usability gap among the end-users regarding the climate services that are provided? If so, could you explain where the usability gap occurs in the existing CS? OR If yes, then how do you define the usability gap? - Follow up
3. How does the usability gap affect the decision making of the end-users? – Both Project partners

Explain the usability gap

1. Why does this usability gap exist? – Follow Up question for the previous section (Probe question)
2. What could be the potential factors influencing the usability gap of the climate services among the end-users? And why?
3. What type of information goal/ purpose do these services provide? (climate effect or impact?)
4. How is the information visually represented? (map,3D, etc.)
5. Do you think the type of information or the type of representation of these climate services play an essential role in decision making for the end-users or both?
6. Who are/is the target audiences for these existing climate services? Or Who is/are the intended audience or end-users that you study in EVOKED?
7. Who are the potential stakeholders involved in implementing climate-adaptive strategies by using climate services?
8. In what way do these climate services help the end-users?
9. Does the existing climate service have a two- way communication or one-way communication? According to you, which method is more effective?
10. Is the information provided in the existing climate services user-friendly?

11. What kind of spatial/ temporal aspect do the climate services provide (assessment frameworks/ evacuation procedures, adaptation measures, etc.)?
12. Does the information provided in the climate services contain demographical, social, economic, technological, political, or ecological aspects? If so, which ones does it contain?
13. Are there any other factors apart from the ones mentioned above, that could potentially cause the usability gap in the climate services? - Follow up

    FOR REFERENCE:
    - Behavioral issue/ Participatory issues
    - Governance issues- levels
    - Coordination/Collaboration
    - Political willingness
    - Lack of resources: Finance, time, technology
    - Communication: Information (DESTEP), Information goal/ purpose, Information framing, Intended audience, 1-way or 2-way communication, Spatial or temporal aspects.
    - Information for decision making/ process of adaptation: Understanding, Planning and managing phase
    - Solutions provided: Adaptation measures

Improve the usability gap

1. What could be done to reduce the usability gap for the end-users?
2. Will the decision-making process and the usability of the climate services improve if the potential factors that were causing the gap are rectified?
3. Are there be any other methods to improve the process of implementing adaptation strategies/ decision-making processes for the end-users? - Case Stakeholders

Ending the interview and thanking the respondents

1. Do you have any personal experiences but still practical insights about "climate services and its (potential)usability gap," that I have not asked about, but that could be interesting for the research?
2. If I have additional questions, could I then contact you for additional information and/or explanations?
3. And will you be interested in the results from my thesis when this is completed?

Thank you very much for taking out some time from your busy schedule and participating in this interview. Your input will be very useful for my thesis.
Goodbye, and have a nice day.

APPENDIX 2: SURVEY QUESTIONNAIRE

Climate services and their usability

- **SURVEY LINK:**

Qualtrics software (SURVEY LINK) -
https://qtrial2019q2az1.az1.qualtrics.com/jfe/form/SV_eu1TW72LlcFp52Z

Survey Flow

Block: Participant's Information (4 Questions)
Standard: Climate Impacts (1 Question)
Standard: Climate Services (14 Questions)
Standard: Identify the usability gap (5 Questions)
Standard: Explain the usability gap (12 Questions)
Standard: Improve the usability gap (2 Questions)

Page Break

Start of Block: Participant's Information

A
Greetings EVOKED partners,

Thank you for agreeing to take part in this survey. Your feedback is very much appreciated.

The purpose of this survey is to examine the potential usability gap between the end-users and the climate services in specific case study areas (EVOKED). This study is not only essential for my master thesis but also crucial for the project EVOKED, where I can draw conclusions from the feedback that I get from this survey and conduct a cross-comparison study of all the cases. My main objective is to identify the usability gap, explain the factors causing the usability gap, and how this can be improved in the future, which will be a part of the recommendations. This survey entails questions based on understanding your perspective on climate services in different case study areas and the potential factors that could be influencing its usability.

You do not have to write your name in this survey. Your response will be completely anonymous, and it will not be linked to you personally. There are 35 questions in total, both open-ended and closed-ended. The approximate time to complete this survey is within 15 to 20 minutes or less. Please read each question carefully and select the answers which best align with your perspective. A few of the questions also have multiple choice answers, which

will be represented in a square box format, whereas the single choice answers will be represented in a circle.

Thank you once again for your cooperation. I am looking forward to your response eagerly.

Best Regards,
Upasana Mukherjee
(Master's student at Radboud University, Nijmegen, The Netherlands & Graduate Intern at Deltares.
In Spatial Planning- Cities, water and climate change)

Click the next button to get started.

Q1 On which case study are you working/ involved with :

- ○ Norway- Larvik (1)
- ○ Sweden- Värmland (Arvika) (2)
- ○ Germany- Flensburg (3)
- ○ The Netherlands- North-east Brabant (4)
- ○ The Netherlands- Fluvius region (5)

Q2 In which organization are you employed?

- ○ Research group (SGI, NGI, University of Kiel, Deltares) Please specify (1)
  _____
- ○ Case Stakeholder (Province, Municipality, Water board etc.), Please specify (2)
  _____

Q3 What is your position at the organization that you are employed in? Please specify.

Q2 = 1

○ Researcher (1) _____

Q2 = 2

○ Stakeholder (2) _____

End of Block: Participant's Information

Start of Block: Climate Impacts

Q4 What are the climate impacts that you find in your case study area?

- ☐ Extreme precipitation (1)
- ☐ Fluvial flooding (2)
- ☐ Heat Stress (3)
- ☐ Drought (4)
- ☐ Forest fires (5)
- ☐ Affected water quality (6)
- ☐ Others, please specify (7)

_____

End of Block: Climate Impacts

Start of Block: Climate Services

B

NOTES:

Climate Service: According to me, any information related to climate effect or impact communicated through any tool, format, portal, or product to different stakeholders to raise awareness, educate and act on implementing climate adaptation /mitigation measures

is called a climate service.

Click the next button to start the next block.

Q5 Are you familiar with the term climate services?

- ○ Yes (1)
- ○ No (2)

Display This Question:

If Q5 = 1

Q6 How would you define climate services?

_____

_____

_____

_____

_____

Display This Question:

If Q5 = 2

Q7 I define climate services as a:

- ☐ Knowledge intensive services to make informed decisions (1)
- ☐ Knowledge about potential solutions and measures (2)
- ☐ Information on social, political, ecological, economic, technical and demographic aspects (3)
- ☐ Service to educate and strengthen awareness (4)
- ☐ Climate data presented in any format (map, brochure, handbook, pictures, 3-D models etc.) (5)
- ☐ Others, please specify: (6) _____

Display This Question:

If Q5 = 2

Q8 Do you agree with this given definition of climate services?

- ○ Yes (1)
- ○ No (2)

Display This Question:

If Q8 = 2

Q9 Why do you disagree with the given definition?

_____

_____

_____

_____

Q10 What types of climate services do these entail:

Q1 = 1

☐ Flood risk awareness (1)

Q1 = 1

☐ Confidence building (2)

Q1 = 2

☐ Regional planning catalog and Geodataportalen (3)

Q1 = 2

☐ MSB- Mapping of slopes and fine grained soils (4)

Q1 = 2

☐ MSB- Flood maps of water courses and coastal (5)

Q1 = 2

☐ SMHI- Regional climate analyses (6)

Q1 = 3

☐ Flood hazard and flood risk maps- Schleswig- Holstein (7)

Q1 = 3

☐ Climate adaptation roadmap of Schleswig- Holstein roadmap (8)

Q1 = 3

☐ Baltic Sea Coast and Climate Change Handbook (9)

Q1 = 3

☐ North German Climate Atlas (10)

Q1 = 4

☐ Regional Climate Portal (11)

Q1 = 4

☐ Stress test light AGRIFOOD Capital (12)

Q1 = 4

☐ Klimaateffectatlas North Brabant (13)

Q1 = 5
And Q1 = 4

☐ National Klimaateffectatlas (14)

Q1 = 5

☐ WDOD Klimaateffectatlas (15)

Q1 = 1
And Q1 = 2
And Q1 = 3
And Q1 = 4
And Q1 = 5

☐ Others, please specify: (16)

_____

Display This Question:

If Q10 = 1

And Q10 = 2

And Q10 = 3

And Q10 = 4

And Q10 = 5

And Q10 = 6

And Q10 = 7

And Q10 = 8

And Q10 = 9

And Q10 = 10

And Q10 = 11

And Q10 = 12

And Q10 = 13

And Q10 = 14

And Q10 = 15

And Q10 = 16

Q11 Which climate impacts of your region are addressed by these climate services?

- ☐ Extreme precipitation (1)
- ☐ Fluvial flooding (2)
- ☐ Heat stress (3)
- ☐ Drought (4)
- ☐ Forest fires (5)
- ☐ Affected water quality (6)
- ☐ Other, please specify: (7)

_____

Q12 Within the EVOKED-project, are there any existing climate services that you are focusing on, which you will be adjusting as part of the project?

- ○ Yes, please specify: (1) _____
- ○ No (2)

Display This Question:

If Q12 = 2

And Q3 = 1

Q13 Could you clarify the choice for (not) using an existing climate service to adjust within the frame of the EVOKED-project?

_____

_____

_____

_____

_____

Display This Question:

If Q3 = 1

And Q12 = 2

Q14 Are you developing any new climate service for the project- EVOKED?

- ○ Yes (1)
- ○ No (2)

Display This Question:

If Q14 = 1

And Q3 = 1

Q15 Please specify the name of the climate service that is being developed and the reason behind developing it.

_____

Display This Question:

If Q3 = 1

Q16 What was the reason behind selecting certain climate services in your region for the project -EVOKED?

- ☐ The targeted audience was wrong (1)
- ☐ The goal of the climate service did not align with the goal of the stakeholder's demands who wanted to use the climate service (2)
- ☐ There was a lack of data in the offered information by the climate service (3)
- ☐ The visualization of the climate service did not match the preferences of the end-users (4)
- ☐ Other, please specify: (5)

_____

Q17 According to you, to what extent are these climate services (not) being used within your organization?

- ○ Not used at all (1) (1)
- ○ Used very rarely (2) (2)
- ○ Used moderately (3) (3)
- ○ Used most of the time (4) (4)
- ○ Used for every decision (5) (5)

End of Block: Climate Services

Start of Block: Identify the usability gap

C

NOTES:

Usability gap: In my perspective, when a climate service is provided for the stakeholders who are responsible for implementing climate adaptive measures, and inevitably these services are not used effectively and efficiently, in regards to implement measure and make informed decisions, there could potentially be a usability gap between the end-users and the climate service. There can be many potential factors that can influence the usability of climate service.

Process of the decision- making: This theory was developed by Moser and Ekstrom, (2010). It is divided into three crucial phases based on adaptive management to deal with complex uncertainties and enhance social learning. The first phase (Understanding phase) comprises detecting the problem, gathering and using the information available, and redefining the problem. The second phase (Planning phase) entails developing options to solve the problem, assessing the options, and selecting the option(s). And the last phase (Managing phase) consists of implementing the option(s), monitoring the option(s), and the environment as well as evaluating.

Click the next button to start the next block.

Display This Question:

If Q3 = 1

Q18 According to you, what are the information needs of the involved stakeholders?

- ☐ Information on social, economic, ecological, demographic, political aspects (1)
- ☐ Information about adaptation and mitigation measures (2)
- ☐ Assessment frameworks and evacuation procedures (3)
- ☐ Climate data and vulnerable areas (4)
- ☐ Others, please specify: (5) _____

Display This Question:

If Q3 = 2

And Q3 = 1

Q19 Do you think there is a usability gap between the end-users and the existing climate services?

- ○ Yes (1)
- ○ Maybe (2)
- ○ No (3)

Display This Question:

If Q3 = 1

Q20 How do you define the usability gap among end-users with regard to climate services?

- ☐ Not using the service to make informed decisions (1)
- ☐ Not being aware about the climate impacts (2)
- ☐ Not implementing measures to adapt to climate change (3)
- ☐ Other definitions, please specify: (4) _____

Q21 How does the usability gap affect the decision-making process of the end-users?

- ☐ During the understanding phase of the problem (1)
- ☐ During the planning phase while selecting an option to solve the problem (2)
- ☐ During the managing phase while implementing the option (3)
- ☐ Other, please specific: (4) _____

End of Block: Identify the usability gap

Start of Block: Explain the usability gap

Q22 What could be the potential factors that could influence the usability gap between the end-users and the climate services?

- [ ] Behavioral issue/ Participatory issues (1)
- [ ] Governance issues at different levels (2)
- [ ] Lack of taking the responsibility (3)
- [ ] Lack of political willingness (4)
- [ ] Lack of co-ordination or collaboration (5)
- [ ] Lack of resources (finance, time, technology etc.) (6)
- [ ] Communication issues (7)
- [ ] Lack of relevant and adequate information (8)
- [ ] Lack of information on adaptation measures (solutions) (9)
- [ ] Lack of stakeholder's information needs (10)
- [ ] Others, please specify: (11)

_____

Q23 What kind of information goal/purpose do these climate services have?

- [ ] Changing the perspective on social norms/ cultural values (1)
- [ ] Raising awareness/educating about climate effect/impacts (2)
- [ ] Increasing social engagement (3)
- [ ] Initiating implementation of climate adaptation/mitigation measures (4)
- [ ] Others, please specify: (5)

_____

Q24 How is the information visually represented?

- ☐ Maps (1)
- ☐ Story Maps (2)
- ☐ Text format/ Brochures (3)
- ☐ Handbooks (4)
- ☐ Scientific articles (5)
- ☐ 3-D modeling (6)
- ☐ Infographics (7)
- ☐ Reports (8)
- ☐ Graphs (9)
- ☐ Others, please specify: (10)

_____

Display This Question:

If Q3 = 1

Q25 Who are the intended audiences or end-users that you study in the EVOKED project to understand the usability of climate services?

- ☐ Local government (1)
- ☐ Regional government (2)
- ☐ National government (3)
- ☐ Water boards (4)
- ☐ Ngo's (5)
- ☐ Landowners (6)
- ☐ Construction developers (7)
- ☐ Politicians (8)
- ☐ Private businesses (9)
- ☐ Nature protection agencies (10)
- ☐ Research institutes (11)
- ☐ Citizens (12)
- ☐ Others, please specify: (13) _____

Display This Question:

If Q3 = 1

Carry Forward All Choices - Displayed & Hidden from "Q25"

Q26 Who are the potential stakeholders responsible for implementing climate adaptive measures?

- [ ] Local government (1)
- [ ] Regional government (2)
- [ ] National government (3)
- [ ] Water boards (4)
- [ ] Ngo's (5)
- [ ] Landowners (6)
- [ ] Construction developers (7)
- [ ] Politicians (8)
- [ ] Private businesses (9)
- [ ] Nature protection agencies (10)
- [ ] Research institutes (11)
- [ ] Citizens (12)
- [ ] Others, please specify: (13) _____

Display This Question:

If Q3 = 1

Q27 There are two types of communication as stated by Moser (2010)One-way communication does not include feedback back from the end-user to the producer of climate services, whereas two-way communication does include this (see figure). Which,

according to you, will be more beneficial to reduce the usability gap between the climate services and the end-users?

- ○ One-way communication (1)
- ○ Two- way communication (2)

Q28 Is the information provided in the existing climate services user-friendly?

- ○ Strongly agree (1)
- ○ Agree (2)
- ○ Somewhat agree (3)
- ○ Neither agree nor disagree (4)
- ○ Somewhat disagree (5)
- ○ Disagree (6)
- ○ Strongly disagree (7)

Display This Question:

If Q28 = 4

And Q28 = 5

And Q28 = 6

And Q28 = 7

Q29 Why do you feel that the information provided in the existing climate services is not user-friendly/ satisfactory? Could you please provide an example?

_____

_____

_____

_____

_____

Q30 What kind of solutions/knowledge do the existing climate services provide?

- ☐ Evacuation procedures (1)
- ☐ Risk assessment frameworks (2)
- ☐ Adaptation and mitigation strategies/measures (3)
- ☐ Others, please specify: (4)

_____

Q31 Does the information provided in the existing climate services contain demographics, social, economic, technological, political, or ecological aspects?

- ○ Yes (1)
- ○ Maybe (2)
- ○ No (3)

Display This Question:

If Q31 = 1

And Q31 = 2

Q32 Could you give some examples of the type of information factors (demographics, social, economic, technological, political or ecological) that are provided in these climate services?

_____

_____

_____

_____

_____

Q33 Are there any other factors apart from the ones mentioned before, that could potentially cause the usability gap in the climate services?

- ○ Yes, please specify (1) _____
- ○ No (2)
- ○ I do not know (3)

End of Block: Explain the usability gap

Start of Block: Improve the usability gap

Display This Question:

If Q19 = 1

And Q20 = 3

And Q20 = 2

And Q20 = 1

And Q20 = 4

And what could be the potential factors that could influence the usability gap between the end-users and the climate services? q://QID27/ChoiceDisplayed Is Displayed

And Q31 = 3

And Q31 = 2

Q34 What can be done to reduce/close the potential usability gap(s) between the end-users and the climate services?

_____

_____

_____

_____

_____

Display This Question:

If Q3 = 1

Q35 Do you have any other suggestions that can improve the decision-making process of the end-users using the climate services?

_____

_____

_____

_____

_____

End of Block: Improve the usability gap

APPENDIX 3: LIST OF CODES TO ANALYSE THE INTERVIEWS

A total of 40 codes and 9 group codes were created to analyze the interviews based on the research question. Following is a table depicting the codes and code groups which are again color-coded based on the groups.

Code (40)	Code Groups (9)
Awareness and education factors	Other influencing factors
Behavioral change and participation	Other influencing factors
Case study area	Climate impacts in the region- Per case
Climate data- abundance	Usability gap of climate services
Climate impacts	Climate impacts in the region- Per case
Climate services	Climate services related
Communication factors	Potential influencing factors
Competence building	Other influencing factors
Decision-making process	Decision-making process and implementing adaptation measures
Developing climate service	Climate services related
EVOKED	EVOKED project related
Existing climate services for target audiences	Climate services related
Experience through representation	Improve the usability gap
External factors	Other influencing factors
The focus of climate service	Potential influencing factors
Goal/ purpose of the climate service	Potential influencing factors
Implementation and decisions on best climate adaptation measures	Decision-making process and implementing adaptation measures
Information factors	Potential influencing factors
Information needs	Potential influencing factors
Involvement - climate services and usability gap	Researcher/ Stakeholder information and background involvement
Monitoring challenge	Usability gap of climate services
More similar approaches- both regional and national level	Improve the usability gap
Organization and department	Researcher/ Stakeholder information and background involvement
Perspective on climate services	Climate services related
Political willingness	Other influencing factors
Reduce the usability gap	Improve the usability gap
Representation of climate service	Potential influencing factors
Researcher-Organization	Researcher/ Stakeholder information and background involvement
Spatial/temporal factors	Potential influencing factors
Stakeholder/Practitioner- Organizations	Researcher/ Stakeholder information and background involvement
Taking responsibility- Challenges	Other influencing factors
Target audience	Potential influencing factors
Targeting different sectors	Climate services related
Test usability of the climate service	Improve the usability gap

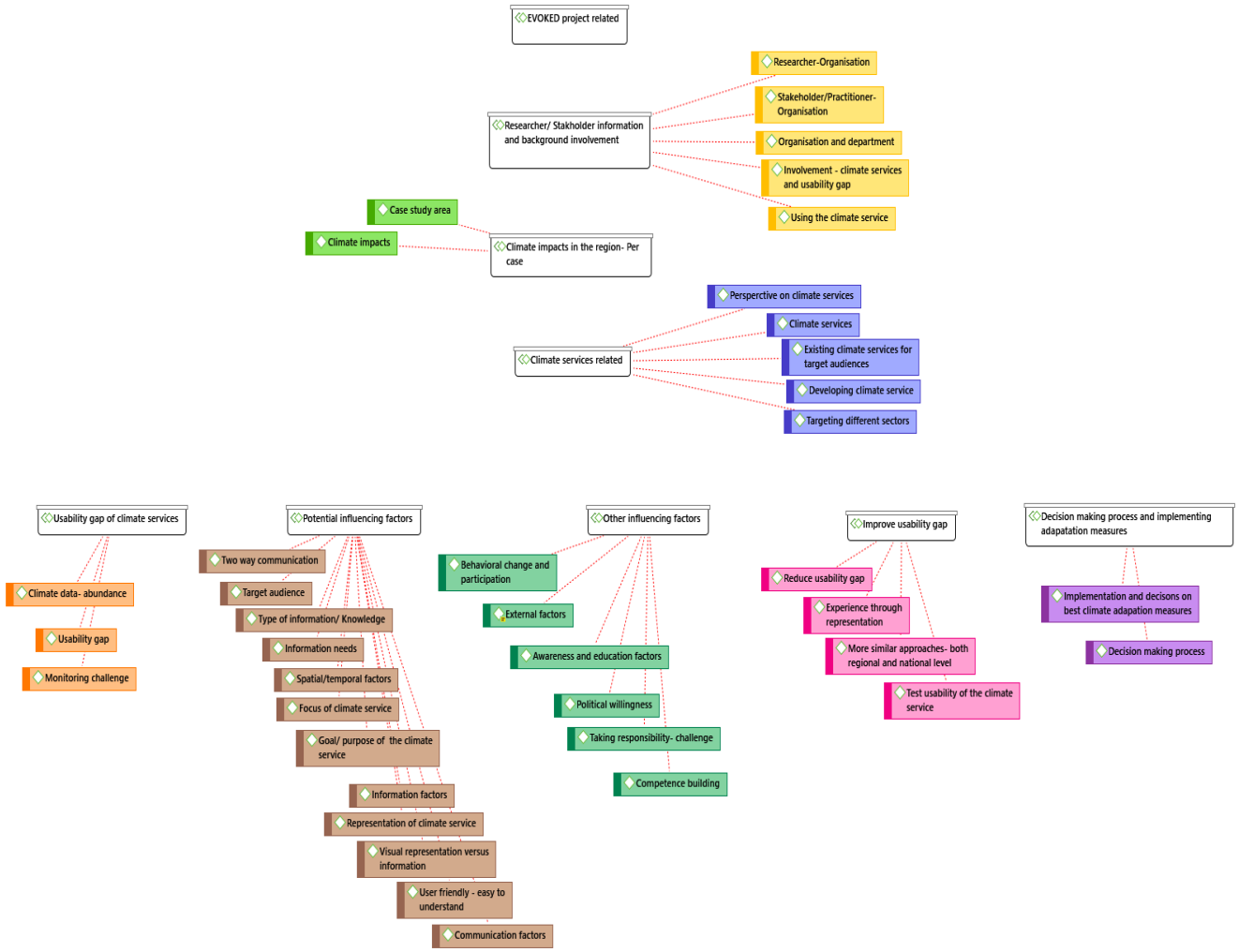
Two-way communication	Potential influencing factors
Type of information/ Knowledge	Potential influencing factors
Usability gap	Usability gap of climate services
User-friendly - easy to understand	Potential influencing factors
Using the climate service	Researcher/ Stakeholder information and background involvement
Visual representation versus information	Potential influencing factors

Usage of codes for the 5 interviews:

Code	Grounded
Organization and department	13
Behavioral change and participation	20
Implementation and decisions on best climate adaptation measures	30
Goal/ purpose of the climate service	19
Using the climate service	7
Test usability of the climate service	17
Spatial/temporal factors	3
Communication factors	17
Competence building	3
EVOKED	22
User-friendly - easy to understand	15
More similar approaches- both regional and national level	3
Representation of climate service	17
Existing climate services for target audiences	6
Experience through representation	5
Targeting different sectors	11
Monitoring challenge	3
Visual representation versus information	10
Awareness and education factors	27
External factors	5
Information factors	23
Researcher-Organisation	7
Stakeholder/Practitioner- Organisation	15
Climate impacts	28
Climate services	38
Information needs	59
Involvement - climate services and usability gap	9
Perspective on climate services	7
Usability gap	30

Two-way communication	17
Developing climate service	37
Case study area	17
The focus of climate service	27
Reduce the usability gap	36
Climate data- abundance	9
Type of information/ Knowledge	22
Decision-making process	21
Target audience	53
Political willingness	1
Taking responsibility- challenge	3

Network for the codes:



APPENDIX 4: LIST OF CODES TO ANALYSE THE DOCUMENTS

A total of 24 documents were analyzed by creating codes on Atlas.ti software, based on specific themes and factors influencing the usability gap. The codes highlighted in red are the factors (6) influencing the usability of climate services based on the conceptual model. There are also other factors mentioned in the list of codes that influence the usability of the services. However, they are not highlighted in red. Following are the list of codes used:

Overall documents (6)	**Larvik - documents (4)**	**Arvika – documents (3)**	**Germany- documents (3)**	**North-east Brabant- documents (3)**	**Drenthe- Fluvius documents (5)**
Codes: Active participation Awareness and understanding gap Case study area Climate adaptation services Climate impacts Climate services Climate services- define Collaboration and Coordination Communication factors Concrete decisions Cross-comparison of case study sites (needs and vision) End-users perspective EVOKED end-users and partners EVOKED-LARVIK needs and vision EVOKED objective Existing climate services Focus of EVOKED-Värmland The goal for Fluvius region The goal for North Brabant	**Codes:** Abundance of knowledge Awareness Case study area Climate impacts Climate-related past experiences Climate services Communication factors Coordination and collaboration Demographics End-users perspective Financial responsibility Geographical location Governance Information factors Information needs Knowledge gap Lack of understanding and using the knowledge Living labs Needs and vision Objectives of Larvik Organization	**Codes:** Abundance of knowledge Awareness Case study area Climate impacts Climate information design Climate-related past experiences Climate services Communication factors Coordination and collaboration Demographics End-users perspective Geographical location Governance Information factors Information needs Knowledge gap Lack of understanding and using the knowledge Living labs Needs and vision Organization Representation	**Codes:** Awareness Case study area Climate impacts Climate information design Climate-related past experiences Climate services Communication factors Concrete decisions Conflict of interest Coordination and collaboration Demographics End-users perspective Financial responsibility Geographical location Governance Information factors Information needs Knowledge gap Lack of understanding and using the knowledge Living labs	**Codes:** Abundance of knowledge Awareness Case study area Climate impacts Climate information design Climate-related past experiences Climate services Communication factors Coordination and collaboration Demographics End-users perspective Existing climate services Geographical location Governance Information factors Information needs Knowledge gap Lack of understanding and using the knowledge Living labs Organization	**Codes:** Abundance of knowledge Awareness Case study area Climate impacts Climate information design Climate-related past experiences Climate services Communication factors Coordination and collaboration Demographics End-users perspective Existing climate services Financial responsibility Geographical location Governance Information factors Information needs Knowledge gap Lack of financial capacity Lack of integration Lack of understandin

Goal of Arvika Goal of Flensburg Goals for Larvik Increase awareness and Competence in building Information design Information needs Living labs Needs and vision Needs for Arvika Needs for Flensburg Needs for Fluvius region Needs for North Brabant Needs of Larvik Organization Past experiences - raise awareness Reduce the usability gap Representation Responsibility Spatial/temporal factors Stakeholder analysis Stakeholders Two-way communication Type of information Urban planning and adaptation measures Usability gap Vision for Arvika Vision for Fluvius region Vision for Larvik Vision for North Brabant vision for Flensburg	Responsibility Risk perception Socio-economic context Spatial/Temporal factors Stakeholders Stakeholders interest Two-way communication Type of information Urban planning and adaptation measures	Responsibility Risk perception Socio-economic context Spatial/Temporal factors Stakeholders Stakeholders interest Two-way communication Type of information Urban planning and adaptation measures	Needs and vision Representation Responsibility Risk perception Socio-economic context Spatial/Temporal factors Stakeholders Stakeholders interest Two-way communication Type of information Urban planning and adaptation measures	Reduce the usability gap Representation Responsibility Risk perception Socio-economic context Spatial/Temporal factors Stakeholders Stakeholders interest Two-way communication Type of information Urban planning and adaptation measures	g and using the knowledge Lack of urgency or active participation Living labs Needs and vision Reduce the usability gap Representation Responsibility Risk perception Sectors Socio-economic context Spatial/Temporal factors Stakeholders Stakeholders interest Two-way communication Type of information Urban planning and adaptation measures

APPENDIX 5: LIST OF EVOKED DOCUMENTS

Sr. No.	***Name of the Document***
1	EVOKED D1.2_Climate services needs inventory_final
2	EVOKED D2.1_Local set of scenarios (narratives and population projections)_final
3	EVOKED D3.1_Field trial framework Guideline_final
4	EVOKED D5.1 dissemination satrategy_final
5	EVOKED D5.2_EVOKED website_final
6	EVOKED Deliverable 1.1_Living Lab Co-Design Requirements Guiding Paper_final
7	Arvika_VCAB_EVOKED template 1.1C needs and visions
8	Arvika_VCAB_Template 1.1E_Context and Governance Analysis
9	WP1__Stakeholder indentification matrix_Arvikapilot_nuläge
10	D1.1 Appendix B_Stakeholder Identification_final
11	EVOKED Territorial Governance Template_180116_final
12	Larvik__EVOKED template 1.1A needs and visions_final
13	Results_Questionnaire_Larvik_08112018
14	EVOKED Territorial Governance Template_Germany
15	EVOKED_Needs and Visions_Flensburg
16	Questionnaire_feedbak_FlensburgCAU_Workshop1
17	Brabant EVOKED Territorial Governance Template_180116_version_19_03_2018
18	Deliverable 3.2 NB_v2
19	Results_Questionnaire_Uden_181101
20	Attachment 2_Stakeholder identification matrix_Fluvius
21	Attachment 2_Stakeholder identification matrix_WDOD
22	Deliverable 3.2
23	EVOKED Territorial Governance Template_Fluvius
24	Needs and visions - Fluvius_12_10_2018