Integration of a Technological Tool in an Early Warning System within its Social Context: A Case Study from Durazno, Uruguay

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Abstract
A disaster is not just natural but largely of social and political origin. To be effective, an early warning system must therefore be viewed as a social process with a strong focus on the people at risk. This contrasts with the conventional view on an early warning system that it is a pure engineering and technological solution, following a linear chain from observation to dissemination of warning. Technology is an important enabling factor for successful disaster risk, and rather than neglecting the technological aspect of an EWS, it should be embraced within its social context. This study aims to contribute to the understanding of the integration of a technological tool in an EWS within its social context through a case study of a flood EWS in Durazno in Uruguay. The study is approached from the perspective of the authorities and scientific developers of a technological decision-making tool at the center of the EWS. The study finds that the decision-making process regarding emergency planning for floods has improved significantly with the technological tool in terms of time to plan response and increased trust of the people in the authorities. The tool plays a significant role in the decision-making process regarding evacuation, and is always used due to the authorities' high level of trust in the tool. Although, the term 'EWS' generally is perceived to only include the technological aspect of the EWS, the study finds that the technological tool to some degree is embedded in its social context. It is, however, only to a limited degree, and the social aspects of the EWS need to be further developed to make it a true effective EWS.

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List of Abbreviations

ANII	Uruguay National Agency for Research and Innovation
CDE	Departmental Emergency Committee
CECOED	Departmental Emergency Coordinating Centre
DINAGUA	Uruguay National Water Directorate
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
EWS	Early Warning System
IMFIA	The Institute of Fluids Mechanics and Environmental Engineering
INUMET	Uruguayan Institute of Meteorology
ITU	Institute of Theory of Architecture and Urbanism
PROHIMET	Ibero-American Network for the Monitoring and Forecasting of Hydrometeorological Phenomena
SINAE	Uruguay National Emergency System
UNISDR	United Nations International Strategy for Disaster Risk Reduction
WMO	World Meteorological Organisation

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1 Introduction

The role of technology as an enabling factor for successful disaster risk reduction (DRR) has gained prominence the last decades, as the disaster community has witnessed a shift in focus from mainly post-disaster response towards mitigation, prevention and planning for disasters (Basher, 2013; UNISDR, 2009a; UNISDR, 2013; UNISDR, 2015a). Successful risk reduction efforts all around the world such as forecast models for early warning systems (EWS) and geographic information systems for risk mapping are just some few examples of how technological tools have contributed to protecting people against devastating disasters and to creating more resilient societies. This increased recognition of the importance of technology is reflected in the Sendai Framework for Disaster Risk Reduction, adopted at the third UN World Conference on Disaster Risk Reduction in 2015, emphasizing that science and technology are essential for effective decision-making (UNISDR, 2015b).

Despite the many advances of technology in DRR that indeed should not be discredited, it is widely recognized that DRR initiatives should not be purely technological enterprises, but take place within their social context (Aitsi-Selmi, 2016; Basher, 2013; Kelman & Glantz, 2014; UNISDR, 2013). Traditionally, decision-makers have given more attention to the view that disasters can be perceived as pure natural hazards that can be analyzed fully by the means of natural science and technology. This view is now being replaced by the view that disasters are not just natural but largely of a social and political origin. Emergencies are about the people at risk, whose needs should be the guiding factor for disaster risk reduction initiatives (Wisner et al., 2004).

EWSs provide a good illustration of this contrast between a pure technological hazard-focused approach and a people-centred approach, incorporating social and human factors. The core stakeholders of an EWS tend to be natural scientists and engineers, and consequently the conventional view on an EWS is that it is an engineering solution of a monitoring and warning system, following a linear chain from observation through warning generation to the dissemination of the warning to users who are expected to act upon it (Basher, 2006; Basher, 2013; Kelman & Glantz, 2014; Parker, 2017). At the center of all EWSs is some sort of hazard-based model that provides information of what might happen in the future to enable action in advance to reduce risk (Basher, 2006). As a result of the conventional view on an EWS, this model, which is often very technological, tend to be equated with the actual EWS, thus ignoring human and social factors within the social context of the EWS.

An example of the conventional view on an EWS is when the performance of a flood early warning is measured as the difference between a flood forecast measured by hydro-meteorologists, truly believing that a forecast is all that is needed to enable early action (Parker, 2017). However, experience has shown that technological predictions are insufficient in themselves to reduce losses and impacts. An EWS also needs to include decision-making processes and other social aspects including the translation of technological warnings into understandable messages to those at risk (Basher, 2006; Kelman & Glantz, 2014; Parker, 2017). Therefore, disaster risk reduction (DRR) literature calls for a shift towards a people-centred view of an EWS as a social process with a strong focus of the people at risk, in which the technological component is integrated. In this light, the Sendai Framework articulates a need to develop EWSs "through a participatory process" and to "tailor them to the needs of users" (UNISDR, 2015b, p. 21).

The call for a shift away from an exclusive technological view to a more holistic view on an EWS as a social process motivated an interest to explore the integration of technological tools and social aspects in an EWS in practice. In 2011, a flood EWS was implemented in Durazno city in Uruguay as a support tool for local decision-makers to improve emergency planning for floods, particularly regarding evacuation planning. Based on a hydrological-hydrodynamic model, this EWS clearly has a sound technological base. However, a better understanding is needed of how the technological tool is integrated into the EWS as a social process.

1.1 Research Aim and Questions

The aim of this study is to contribute to the understanding of the integration of a technological tool in an EWS within its social context. This is done through a case study on a flood EWS in Durazno in Uruguay. From the perspective of the authorities and the scientific developers of the technological decision-making tool for the EWS, the study seeks to examine in how far the technological component is included in a social context. To achieve this aim, the thesis answers the following research questions (RQ):

- RQ1: To what extent does the EWS integrate all essential elements of an effective people-centred EWS?
- RQ2: How has the technological tool developed for the EWS in Durazno impacted decision-making regarding emergency planning for floods?

- RQ3: What are the roles of the technological tool developed for the EWS and social factors respectively in the decision to initiate a flood evacuation in Durazno?

1.2 Thesis Outline

To gain a better understanding of the conceptual framework, chapter two introduces key terms used in the study. The following third chapter presents the case study context, including the legal framework in Uruguay, a description of the study area and the background for the EWS and furthermore a stakeholder mapping. Chapter four then moves on to describe the methodology, including philosophical considerations guiding the study, research approach, and research reflections and limitations. In chapter five, the research questions RQ1, RQ2, and RQ3 are answered, and the implications of these findings are discussed in chapter six. Finally, the conclusion is presented in chapter seven.

2 Conceptual Framework

How disaster risk is managed, including how technology is being used, depends on the conceptual framing of the disaster problem. In this thesis, several terms are used, which need to be clarified to comprehend the results and discussion. This chapter therefore provides definitions of the most important terms as they are used in this thesis.

2.1 Disaster, Risk and Vulnerability

A disaster can be defined as “a serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources” (UNISDR, 2009b, p. 9). This definition reflects the view that a disaster is not just a hazard, but also a product of social, political and economic environments (Wisner et al., 2004). For instance, if a flood occurs in an area with no people and no constructions to affect, it might be received as a necessary event to prevent erosion or to make the soil fertile for farming. Only when the hazard causes a disruption of the functioning community or society, it turns into a disaster.

Disaster risk is a fundamental concept in DRR with several competing definitions, involving some aspect of uncertainty and adverse effects in the future (Aven, 2012; Cardona et al., 2012). Risk in itself is not real. It is a social construction, which can be seen as a continuum of potential disasters. In this terminology, a disaster is a materialization or outcome of the risk conditions (Cardona et al., 2012; UNISDR, 2009). In this thesis, disaster risk is defined in very close proximity to the definition of a disaster, conceptualized by the pseudo-equation:

$$Risk = Hazard * Vulnerability$$

(Wamsler, 2014; Wisner et al., 2004).

Thus, hazard and vulnerability are the factors determining disaster risk. Hazard refers to possible future events that are dangerous and may have negative consequences for exposed elements. Vulnerability is on the other hand a more complex concept. Vulnerability is the component that brings a societal and non-physical aspect to risk and disasters. The concept emphasizes “that society, in its interaction with the changing physical world, constructs disaster risk by transforming physical events into disasters […]” (Cardona et al., 2012, p. 70). UNISDR (2009) describes vulnerability as “the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effect of a hazard" (p. 30), which can be of a physical, social, economic or environmental nature. For instance, these characteristics and circumstances can be apparent in poor building structures, corruption, lack of education and deforestation, which are factors affecting an individual's or institution's ability to cope with a hazard. Although vulnerability is in general seen as a hazard-specific concept, which also agrees with UNISDR's definition, some factors however make people more prone to the impacts of hazards regardless of the type of hazard. These vulnerability factors include, inter alia, poverty, disability and health status (Cardona et al., 2012; Wisner et al., 2014).

UNISDR's definition of vulnerability excludes exposure from the components constituting the concept of vulnerability, since vulnerability is identified as a characteristic of the elements at risk. However, vulnerability is a concept with no clear consensus on its meaning, and vulnerability is often conceptualized, including exposure as a component (Gallopín, 2006). Exposure is a necessary condition for vulnerability, but not sufficient (Cardona et al., 2012). For this study, exposure is included in the concept of vulnerability.

2.2 Early Warning System

An EWS is defined as a "set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss" (UNISDR, 2009, p. 12). In accordance with most DRR literature on EWSs (e.g. Basher, 2006; Kelman & Glantz, 2014), this definition implies that an EWS is not only technological but includes a social component of enabling those at risk to prepare and act appropriately to avoid harm.

For an EWS to be effective and complete, it should be people-centred and four inter-related elements should be integrated: risk knowledge, monitoring and warning service, dissemination and communication, and response capability (Basher, 2006; UNISDR, 2006). Given the above definition of risk, risk knowledge includes knowledge of the relevant hazard, but also knowledge of the vulnerabilities of people and society to these hazards. The monitoring and warning service is the technological capacity to monitor hazard precursors, forecast the evolution of the hazard and to issue warnings. Though often wrongly equated with the complete EWS, this is nonetheless an important element of the EWS. For a warning to be effective, it must reach those at risk. The third element, dissemination and communication, therefore includes the dissemination of clear and understandable warnings to those at risk and pre-defined communication systems. Finally, response capability denotes the knowledge and capacities for appropriate and timely action by the authorities and those at risk. Education and preparedness programs play a key role for the people to understand their risks and to know how to act.

An important characteristic of an effective people-centred EWS it that it should be a collaborative process, involving a range of participants with the aim of protecting the people at risk. These actors include, the communities at risk, that should be actively involved in all aspects of the EWS, government agencies, non-governmental organizations and scientific experts from all relevant disciplines – natural, environmental, social, economic and engineering sciences (Aitsi-Selmi, 2016; Basher, 2006; Basher, 2013; Kelman & Glantz, 2014).

3 Case Study Context

Uruguay is a country that historically has not suffered frequently from major disasters. However, during the last decades the country has experienced a huge increase in the number and severity of hydrometeorological phenomena such as floods and droughts with significant economic impacts (UNDP & the Government of Uruguay, 2012). In May 2007, the worst flood in fifty years happened in Uruguay, when heavy rain caused rivers to overflow in central Uruguay, forcing more than 12,000 people to evacuate (Aragón-Durand, 2014; Piperno & Sierra, 2009). The impacts of this event and other severe events during the last years have alerted the country about the importance of disaster prevention, and recent institutional changes have therefore been made to foster a culture of DRR. As part of this new focus on DRR in Uruguay, the flood EWS in Durazno city was developed with the objective to support local decision-makers to improve emergency planning for floods.

In this chapter, the legal framework for Disaster Risk Management (DRM) in Uruguay, the study area, the background of the flood EWS and the relevant stakeholders are presented.

3.1 Legal Framework for Disaster Risk Management in Uruguay

DRM in Uruguay is an inter-institutional task without a specific body of civil protection. The legal framework for DRM in Uruguay is established through the National Emergency System (SINAE), created through Law 18.621, approved in 2009, as a permanent system of coordination between the public institutions in DRM. The objective of the SINAE is to protect people, high-value assets, and the environment from disasters with the appropriate use of available public and private resources to create conditions for sustainable national development (Law 18.621, 2009) (see appendix 6).

An important principle of the SINAE is decentralization of governance and subsidiarity of actions, which means that risk reduction and disaster response primarily takes place on a local level in the 19 departments of Uruguay. When a situation transcends the technical capacities and resources of actors on a local level, these capacities are complemented by support from higher levels of government (Law 18.621, 2009).

The highest decision and coordination body within the SINAE is the Executive Power, under the Presidency of the Republic, which has the responsibility for the approval of general policies, regulation proposals, national plans for DRR and emergency response, rehabilitation and recovery plans, and the declaration of a state of disaster. The direct link between the Executive Power and the other bodies within the SINAE is the National Directorate of Emergencies, which is responsible for the coordination of the SINAE on a national level, in accordance with the policies and strategies defined by the Executive Power and respecting the autonomies and competencies of all institutions. Tasks of the National Directorate include to promote public education and citizen information campaigns on DRR and training activities for the entities within the SINAE, propose DRR tools to be approved by the Executive Power, taking into account the specific types of contingencies, and to propose policies and strategies of DRR to the Executive Power (Law 18.621, 2009). Although the National Directorate is established through Law 18.621 from 2009, it did not take form before 2015, when a National Director was appointed.

On local level, the Departmental Emergency Committee (CDE) is the body responsible for the formulation of local policies and strategies for DRM in line with national policies. The CDE is composed of the mayor of the respective department or somebody designated in his place, who is the chair of the committee, the departmental police chief, the fire chief, and representatives from the Ministry of National Defense, the Ministry of Social Development (MIDES), and the Ministry of Public Health. Among their tasks is to issue alerts for areas within the department, communicate the alerts to the National Directorate and request the National Directorate to declare a state of disaster when necessary. Furthermore, the CDE should promote that each entity, national or departmental, that operates in the respective department complies with the SINAE and within their areas of competence (Law 18.621, 2009).

In addition to the CDE, a Departmental Emergency Coordinating Centre (CECOED) is installed on local level in each department, coordinated by an official with extensive knowledge in DRM, who is appointed by the mayor of the respective department. The CECOED is under the direction of the CDE and should support the work of the CDE with risk information (Law 18.621, 2009).

3.2 Study Area

Durazno is the capital city of the department of Durazno in central Uruguay as shown in Figure 1. The population is around 30,700 people, with approximately 5,000 people living in high-risk flood areas (Silveira et al., 2012). The flood risk zone is mainly used for housing, but also non-residential structures such as churches and critical infrastructure, including a water treatment plant, pumping station, electrical substation, schools and a cemetery, and some recreational facilities (IMFIA et al., 2012).

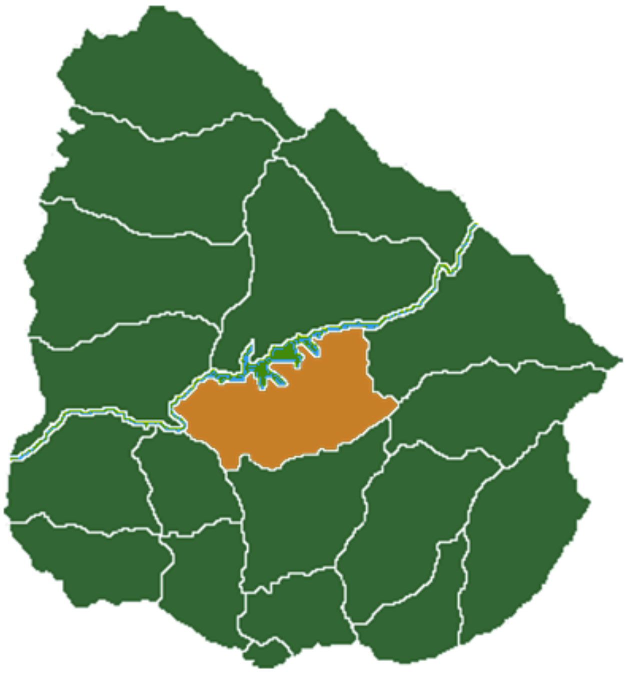

Figure 1 - Location of Durazno Department in Uruguay (Source: SINAE http://sinae.gub.uy/sinae-en-el-pais)

Located on the left bank of Yi River, a tributary to Río Negro, Durazno is among the most flood-prone urban areas in Uruguay (Silveira et al., 2012). Throughout its history, Durazno has had a high recurrence of floods, which seem to have exacerbated during recent years. Until 2007, the worst flooding known was in 1959, but floods from 2007, 2010, 2014, 2015 and 2016 did not only exceed the water level from 1959 but also the number of affected people. In May 2007, the department experiencing the most severe impacts from the flood was Durazno, with 6,000 inhabitants evacuated in Durazno city, corresponding to approximately 20 percent of the population (Silveira et al., 2012). The main social-economic consequences were interruption of activities in schools and colleges, health problems and infrastructure damage such as suspension of water supply, overflow of wastewater treatment plant, damage to roads, and houses completely destroyed (Aragón-Durand, 2014; Silveira et al., 2012).

3.3 Background of the Flood Early Warning System in Durazno

The first steps towards the Flood EWS in Durazno started officially in 2009 with the first letter of agreement of the PROHIMET-Yi project called "Pilot project for the early warning system of the Durazno city under Yi river floods," financed by the World Meteorological Organization (WMO). The project was of inter-institutional character, led by the Institute of Fluid Mechanics and Environmental Engineering (IMFIA) at the Faculty of Engineering, University of the Republic (Uruguay), with the participation of several other institutions. The resulting Flood EWS has been operating in Durazno since its implementation in 2011 at the end of the PROHIMET-Yi project. From 2013 to 2017, another project "SATI-UY: Early Warning System for Prevention and Management of Floods", financed by the National Agency for Research and Innovation (ANII) and led by IMFIA, was carried out to improve the EWS in Durazno and to develop an equivalent EWS in Artigas in the north of Uruguay.

According to the final reports for the PROHIMET-project and the ANII-project, the EWS in Durazno was developed as a support tool for decision-making for the management of floods to optimize the response to floods, particularly regarding evacuation planning (see appendix 5). The reports acknowledge that for an EWS to be effective, all of the four components should be integrated: risk knowledge, monitoring and warning service, dissemination and communication, and response capability. Nevertheless, the EWS in Durazno is defined as a technological tool, consisting of four components (IMFIA et al., 2017).

The first component is the acquisition of input data for the hydrological-hydrodynamic model. The input data required is real-time rainfall forecasts as well as real-time observed rainfall once a rainfall event has begun over the basin. For the meteorological forecasts, four different sources are considered. For the rainfall records, two sources are used; a telemetric network in River Negro with hourly rainfall data, and a network of rain gauges, which are being measured once a day.

The second component is a river level prediction system, which refers to the hydrologic-hydrodynamic modelling of the behavior of the river basin to estimate the evolution of the water level of River Yi in Durazno. For each of the four meteorological forecasts, a hydrograph showing how the river level is predicted to change over time is generated.

The third component of the EWS is a spatial information system, which analyzes the exposure of the potential affected urban elements, using the predicted river level, and estimates the expected impacts of the flooding on people, housing, and infrastructure. The spatial information system provides information on the number of potentially affected people and houses, the location of potentially affected people with disabilities, and potentially affected infrastructure services, which the CECOED has access to through a geographic information system.

Maximum flood level	**Alert level**	**Alert**	**Impact**
Less than 6.83 m	Green	No alert	No impact.
6.83 m – 9.63 m	Yellow	Advisory	Some anthropogenic activities such as public spaces and sports facilities are affected.
9.63 m – 11.14 m	Orange	Security	The first house is affected, requiring evacuation.
11.14 m – 14.85 m	Red	Substantial impacts	Medium risk areas of the city are affected, generating an increase in the number of people needing evacuation.
More than 14.85	Purple	Extreme impacts	Critical infrastructure is affected, having impacts on the city as a whole, in terms of road accessibility and drinking water supply etc.

Figure 2 - Alert levels and corresponding maximum flood levels and impacts in Durazno city (Source: IMFIA, 2017)

Finally, the fourth component is a web page, illustrating the results to be consulted by involved institutions and in particular by the CECOED. On this web page, the maximum predicted flood level from the four forecasts is translated into an appropriate alert level. The different alert levels, green, yellow, orange, red and purple, correspond directly to different levels of impacts, identified in the spatial information system. Figure 2 illustrates the alert levels and the corresponding flood levels in Durazno city. If the alert level is not green, the web page furthermore presents the predicted maximum level of Yi River in Durazno city and the expected date of occurrence, a graph showing accumulated rainfall recorded and predicted over time, a map of the spatial distribution of the daily and accumulated rainfall recorded, evolution of observed river levels, and a hazard map showing the maximum area predicted to be flooded in Durazno.

3.4 Stakeholders

Figure 3 depicts the relevant stakeholders for this study involved in the Flood EWS in Durazno categorized into three groups: academia, local governmental bodies and national governmental bodies.

The two scientific actors are the IMFIA and the Institute of Theory of Architecture and Urbanism (ITU) at the University of the Republic. The IMFIA is the developer of the hydrological-hydrodynamic model and was furthermore the leading actor in the two projects on the EWS (IMFIA et al., 2012; IMFIA et al., 2017). The responsible actor for the development of the spatial information system was the ITU. After the extreme flooding events in 2007 and 2010, ITU started a joint work with the local authorities in Durazno and carried out a field survey to obtain information on vulnerabilities of the affected areas after the flood in 2010, which served as a basis for the development of the spatial information system within Project PROHIMET.

On the local level, the stakeholders are the CECOED Durazno and the CDE Durazno. By law, the CECOED plays a central role in the functioning of an EWS since one of its tasks is to “receive, systemize and transmit necessary information to the Departmental Emergency Committee to identify phenomena that may activate operation, and to continue monitoring the development of these phenomena” (Law 18.621, 2009). Thus, the function of the CECOED regarding the EWS is to monitor the information from the web page and to present it to the CDE, which is the responsible institution for making the political decisions regarding response and to disseminate the information to the citizens.

On the national level, the National Directorate of Emergencies is a central actor as it is a priority of the SINAE to promote the development of capacities to ensure an efficient and coordinated response to emergencies. The National Directorate plays an important role in the future management and sustainability of the EWS.

Another actor on the national level is the National Water Directorate (DINAGUA) under the Ministry of Housing, Territorial Planning and Environment, which has the responsibility of formulating national water and water and sanitation policies. DINAGUA has supported the development of the

EWS by providing topographic information for the hydrological-hydrodynamic models as well as implementing telemetric stations to measure rainfall. DINAGUA will also play an important role in the maintenance of the EWS in the future since one of its objectives in the National Water Plan is to "carry out actions aimed at the development of flood EWSs (with priority in cities with high flood risk) and to establish coordination between these systems, thus generating a national early warning system" (IMFIA et al., 2017, p. 47).

Finally, the Uruguayan Institute of Meteorology (INUMET) is one of the rainfall forecast sources used for the prediction of river level and has moreover committed to the maintenance of the EWS in the future together with the other national institutions (IMFIA et al., 2017).

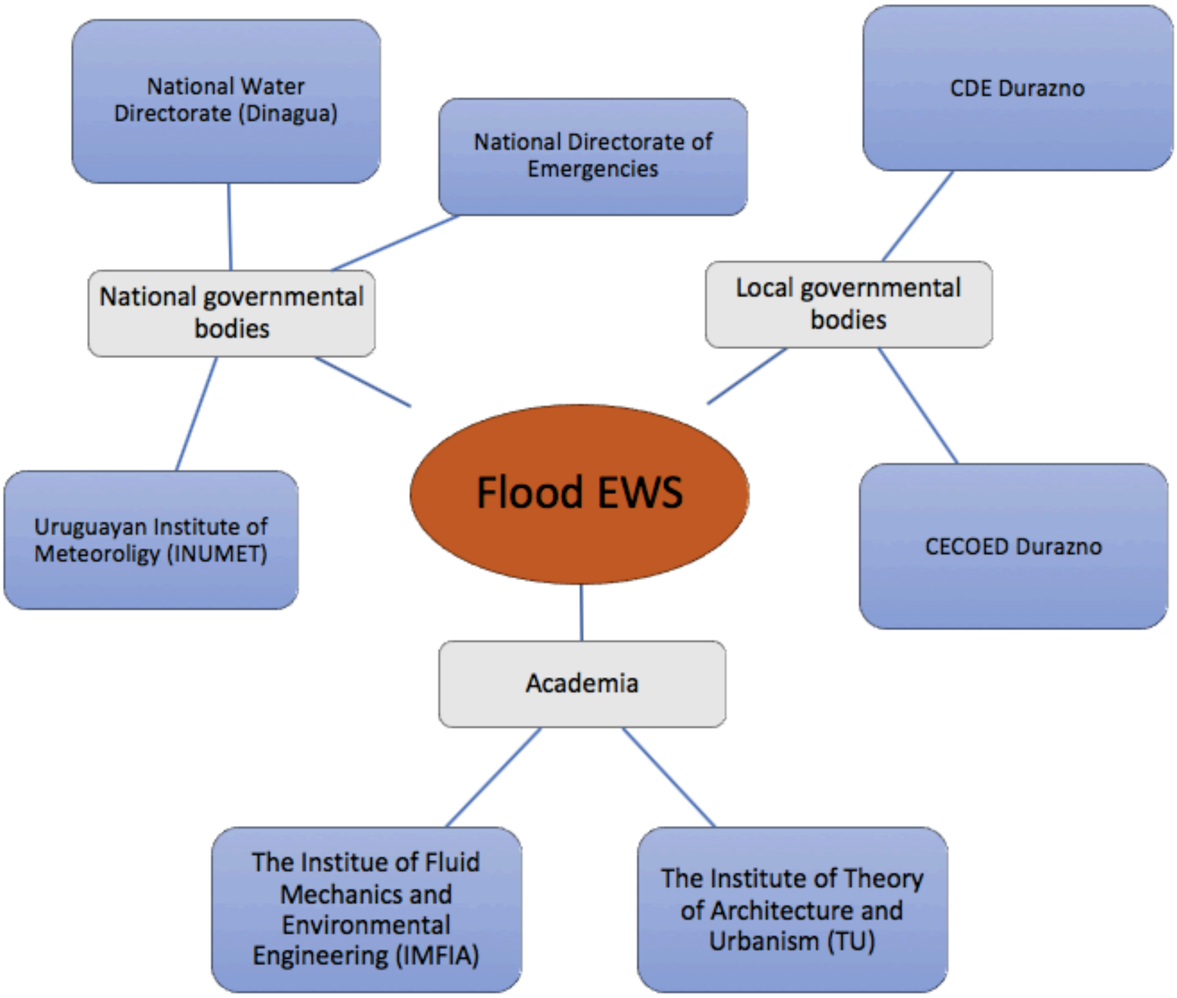

Figure 3 - Relevant Stakeholders (Own Illustration).

4 Methodology

In this chapter, the philosophical considerations guiding the study, the research approach, and research reflections and limitations are presented.

4.1 Philosophical Considerations

In this study, an anti-naturalistic position to social science was adopted, refusing that knowledge in social science can be obtained through the same methods as in natural sciences, characterized by causal explanation (Flowerdew & Martin, 2013). Epistemologically, a hermeneutic view on knowledge was adopted, where the aim not only is to explain social phenomena, but also understand the phenomena, emphasizing the purpose and intentions of human behavior and thoughts and feelings (Bauman, 1978). This epistemological view was considered appropriate since this study seeks to examine the topic from the perspective of the authorities and scientific developers of the technological tool in Durazno. A qualitative research strategy was employed with an inductive approach to the relationship between theory and research, in which generalized inferences and reflections are drawn from observations and findings. By its very nature, qualitative research is focused on words rather than quantification and therefore well-suited to answer exploratory research questions as employed in this study (Bryman, 2012).

The position that researchers should be as objective and value-free as possible in their research has long been a widely accepted view. However, taking an anti-naturalistic position to social science, the study agrees with Letherby et al. (2013) that the role of values in qualitative research cannot be ignored, and that the role of the researcher and study participants as subjective beings should be embraced. The recognition and acknowledgement of values is significant in relation to the term 'risk', which is a central concept in this study, inherent in the concept of an EWS. Tehler (2015) advocates that "if we did not care about anything, there would be no risk" (p. 3.), and it is therefore crucial to be reflective of the values possessed by each individual. Therefore, rather than attempting to be objective in the research, the researcher instead embraced their academic background in DRR. A value formed by this background is to protect the people at risk from harm from disasters, which has been a guiding principle throughout the study. Therefore, as in accordance with most DRR literature, the researcher perceives a disaster as including a human and social aspect. Consequently, the researcher does not have a pure technological view on an EWS as in the conventional view but a people-centred view with a strong social focus on the people at risk. Although, the importance of values thus is acknowledged in the research study, an objectivity in terms of being self-reflective in the research and not imposing the researcher's values on other parts was not abandoned. For example, the questions for the interviews carried out as part of the study were carefully formulated not to impose any preconceived view on an EWS on the respondents. Rather, the qualitative research approach was used as "an opportunity to explore the subjective values, beliefs and thoughts of the respondents" (Davidson & Layder, as cited in Flowerdew & Martin, 2013, p. 112).

4.2 Study Design

A single case study design was employed in the research. A common critique of case studies is that the findings cannot be generalized to a broader context and therefore cannot contribute to scientific development. According to Blatter & Haverland (2012), this view has its roots in the epistemological foundations of logical positivism, deducing causal inferences based solely on empirical observations and formal logic. The epistemology foundation in this study is however hermeneutics, in which the behavior and perspectives of the stakeholders in the FEWS in Durazno are seen as meaningful in-depth information that can contribute to the development of new knowledge on a micro level.

The type of case analyzed in this study can be considered to be what Yin (2009) describes as a 'representative' or 'typical' case. An EWS based on a technological forecasting model as in the case of Durazno is not very unusual. Therefore, the case of Durazno is not chosen for its uniqueness but to exemplify a common case of the integration of scientific tools in an EWS within its social context. According to Yin (2009), although it is not possible to directly generalize from one case to another, the lessons learned from a representative case can be assumed to be informative about experiences in other similar cases. The findings in this study about the flood EWS in Durazno case therefore contributes with lessons learned to be applied in a broader context than the specific case.

4.3 Data Collection

The collection of data consisted of three components, namely a literature review, a document review and qualitative interviews. The data collected was triangulated such that all the components complemented each other in an interactive, non-linear way (Bowen, 2009).

4.3.1 Literature Review

To identify previous research on the topic, an extensive literature review was conducted. The review was carried out to inform the theoretical context on the specific case as well as to put the case into a broader context on the integration of scientific tools in an EWS within its social context and DRM in general. Scientific articles about the FEWS in Durazno was provided by the developers of the scientific model from IMFIA, and further literature was selected by consulting the search engines: Scopus, Web of Science and Google Scholar. Basing the searches on key terms such as "people-centred early warning system," "early warning decision-making" and "DRM science and technology" papers of specific importance to the topic were identified, and thereafter the snow-balling method was used to identify additional literature.

4.3.2 Document Review

To complement the primary data collected during field work, two types of relevant documents were reviewed: legal documents on DRM in Uruguay and final project reports on the FEWS in Durazno. According to Bowen (2009), a document review can serve several purposes. In this study, the legal documents provided data on the context in which the FEWS operates to create an understanding of the legal framework for DRM and to map the relevant stakeholders. The project reports provided data for the background of the EWS in Durazno and were furthermore analyzed as part of the research.

Initially, three legal documents and three project reports were reviewed, of which one legal document and two reports were identified to be relevant for this study (see appendix 5 and 6). All documents were available in Spanish. The legal documents were retrieved from the SINAEs website, and the project reports and the flood evaluations were provided by the IMFIA.

4.3.3 Semi-structured Interviews

The main method applied to answer the research questions was semi-structured, in-depth interviews. In contrast to structured interviews, semi-structured interviews follow a conversational mode, aiming "to understand the participant's own world" (Yin, 2010, p. 135). The interviews were therefore based on developed interview guides (see appendix 1, 2, 3 and 4) but allowed at the same time for flexibility and adaptation to the flow of the interviews.

Relevant respondents were identified from the document review and were all carefully selected by virtue of their relevance for the research, resulting in a high confidence in the sample. Some of the respondents were obtained through the researcher's personal network, and the rest were obtained through snowballing, using contacts to recruit new contacts. In total, seven interviews were conducted with the following respondents:

- Two representatives from the IMFIA that both had leading roles in the development, implementation, and further improvement of the hydrological-hydrodynamic model for the EWS.
- Three representatives from the CECOED Durazno, including the head of office, who is responsible for the communication with the IMFIA and the CDE regarding the EWS.
- The representative from the Ministry of Social Development (MIDES) in the CDE Durazno. The role of the MIDES within the CDE is to take care of the social, psychological and economic aspects of people in emergency situations. It is the mayor, the chair of the CDE, who decides whether to convene the committee, based on the information received by the CECOED, but the decision to activate a response is made in collaboration with all the members of the CDE, including the representative from the MIDES.
- The National Emergency Director of the SINAE.

The interviews were planned to be carried out during a field work study in Uruguay in February, but due to difficulties regarding coordination, most of the interviews were ultimately carried out over Skype the following months. Six of the seven interviews were conducted in Spanish, and the last interview was conducted in English with some explanations in Spanish. All interviews were recorded to ensure that no vital information was lost, and the records were thereafter all transcribed for data analysis.

4.4 Data Analysis

For the data analysis, a first step was to read through all the material and write down comments and memos for each interview transcript and the two project reports. This helped to get an overview of the material before the actual coding process. The coding process was carried out using NVIVO software to identify recurrent themes relevant for the study (Bryman, 2012). In the end, seven codes were identified and subsequently classified into three categories, corresponding to the three research questions. Finally, the emerging results from the coding process were compared and discussed against existing literature on the topic.

The hermeneutic view on knowledge, adopted in this study, guided the analysis by basing the coding process to a large extent on component parts, identifying the respondents' understandings, experiences and opinions on the topic.

4.5 Reflections and Research Limitations

In an initial stage, one research question was focused on the barriers for the decision-makers' adoption of the technological tool. As it was already clear after the first few interviews that the tool generally is perceived to be very successful, it was assessed that it would not be possible to answer this research question. The question was therefore slightly changed to focus on the role of the tool in decision-making regarding evacuation. This represents a limitation in terms of a different focus in the first interviews conducted but also an opportunity to follow up on significant points mentioned by the respondents. As advocated by Bryman (2012), the flexibility of qualitative research is important to allow for the adjustment of the emphases in the research as a result of significant issues emerging in the interviews.

Furthermore, due to difficulties regarding coordination and reaching relevant informants, the extent of data collected through semi-structured interviews was limited. By including the perspectives of more actors, a better holistic understanding of the FEWS would have been reached. However, the seven interviewees participating in the study were of high relevance for the research, and the quality of these interviews were assessed to be of higher importance than the quantity of interviews conducted.

Finally, the researcher is not from Uruguay nor a native Spanish speaker, which may have led to a limited understanding of the cultural and historical context and created some language barriers. It was assessed that the quality of the interviews would be better if they were conducted in Spanish than in English, so that the interviewees could express themselves more freely. The one interview conducted in English reflected this assumption since the interviewee needed to switch to Spanish several times to explain themselves more comprehensively. The language barriers might have resulted in some misinterpretations and difficulties in following up on ideas brought up by the interviewees. However, before conducting the interview the interview guides were proof-read by Spanish native speakers, and the interviewees were furthermore informed of the researcher's Spanish level to pay attention to not speaking too fast.

5 Results

This chapter presents the main findings of the study, organized into three subsections, corresponding to the thematic areas in the analytical coding process: i) People-Centred Early Warning System, ii) Impacts of the Technological Tool on the Decision-Making Process for Emergency Planning, and iii) Roles of the Technological Tools and Social Factors when Initiating an Evacuation.

5.1 People-Centred Early Warning System

To answer RQ1, this section demonstrates that: (i) the general perception of the scope of the EWS is that it only includes the technological decision-making tool; (ii) the risk knowledge and the monitoring and warning service elements are provided by the technological decision-making tool; (iii) although generally not perceived to be part of the EWS, the communication and dissemination and the response capability elements are also present to a limited degree but need to be developed further in the future; and (iv) the general approach to early warning in Durazno is top-down, not allowing the people at risk to feel ownership.

5.1.1 The Perception of the Scope of the Early Warning System in Durazno

Several of the respondents stressed that the fundamental reason for having an EWS is to protect the people at risk. It is of social nature. As two of the respondents pointed out, if there were no families living on the riverbank, there would be no need for an EWS, and it would probably never have been developed. One of them commented that "if there are no potential evacuees, there is no flood," thus acknowledging the importance of the people at risk. Another respondent noted that in his opinion, an EWS is better than structural mitigation measures to reduce risks, since an EWS allows to reduce the vulnerabilities of the people at risk and not just hazard exposure.

Despite this understanding that an EWS is of a social nature, six out of the seven respondents generally referred to the technological decision-making tool when using the term 'EWS' as in accordance with the definition in the project reports. For example, one of the respondents commenting on the importance of families living on the riverbank also noted that this social aspect "is actually beyond the system," which is just providing information on predicted river level. According to him, the EWS will work the same whether there are people living in the area that the river will reach or not since "the EWS will continue to work well technologically and engineeringly anyway." Another example revealing the respondents' technological perception of the scope of the EWS is that the respondents from the CECOED described their role in relation to the system as "to monitor the EWS." What was actually meant was the web page, illustrating the results of the hydrological modelling and the spatial information system. In addition, when talking about the challenges of copying the EWS and implementing it in another river basin, one respondent commented:

> "It cannot be copied and put in another computer, and then it just works. A study of the particular basin has to be conducted to know the velocity of the river and so on. And satellite information of the specific area is also needed. It is not a copy and paste work."

This quote reveals that the respondent perceives the EWS as a technological tool that can be accessed through a computer. To implement the system in another place than Durazno, no factors regarding communication and response capacity are mentioned, but only location specific data to develop the hydrological-hydrodynamic model and the spatial information system.

In addition to referring to the EWS in technological terms, most of the respondents noted that the users of the EWS are the authorities, and that the system "generates information to base decisions on." This illustrates that the EWS itself is not thought of as incorporating the decision-making process and the people at risk, but purely as a tool for the decision-making regarding response to floods.

Although six of the seven respondents mostly referred to the technological tool by the term 'EWS', the two respondents from IMFIA both referred to the EWS in a broader context once. The first one commented that the "EWS as a whole also involves the population and other institutions than IMFIA." The other one noted that the role of the university is to develop knowledge, to develop new tools, or to improve the system, but not "to be part of the daily operation of the system for example in the decision-making process of when to evacuate," thus indicating that the decision-making process is also integrated in the EWS. Only one respondent, the national director of SINAE, always used the term 'EWS' in a broader sense, including all of the four components of an effective EWS and not only the decision-making tool. The respondent explained that the institutions within SINAE is involved in the EWS in all its components:

> "We are part of the EWS in all its areas. We are not only part of one area. Probably, SINAE is more linked to risk knowledge, communication and response capability than monitoring and warning service, because monitoring and warning is more the

> responsibility of the university and the DINAGUA. However, SINAE is also involved in monitoring and warning through the DINAGUA."

According to this respondent, until now the focus given to the EWS has been related to the hydrological-hydrodynamic modelling, and furthermore in less degree to vulnerability knowledge. It has been developed as a technological and academic work to be used by decision-makers to plan the response. So far, the components of the EWS involving communication, training of people, and involvement of people have almost been invisible, and it is in this light that the scope of the EWS in Durazno is mostly perceived to only include the technological tool for decision-making.

5.1.2 Integration of the Four Elements of an Early Warning System in Durazno

This subsection examines the extent of each of the four elements of an effective EWS in the case of Durazno, although not all of the components are generally thought to be part of the EWS as emphasized in the previous subsection.

Several respondents commented that the first element, risk knowledge, is given by the technological support tool for decision-making through the spatial information system developed by the ITU. Knowledge on the first risk factor, hazard, is provided by the hazard map illustrated at the system web page and by a previous study of the Yi basin in Durazno that has identified return periods for floods in Durazno based on historical data (Silveira et al., 2012). Regarding the second risk factor, vulnerability, one respondent noticed that "it is not enough to know about the hazard but also the vulnerabilities," which is in accordance with the definition of risk for the purpose of this study. According to the PROHIMET-project report, the spatial information system developed by ITU is the component that provides vulnerability knowledge:

> "Risk is understood as the relationship between hazard and vulnerability. Therefore, in order to reduce risk, once the hazard characteristics are identified, it is necessary to identify vulnerabilities of the territories that are likely to be affected. To this end, a spatial support system is developed for the operation of the emergency, […], identifying the potential impacts and supporting the local actors."

In a first stage, in the ANII-project, the spatial information system was based on a field survey of the affected area of the flood in 2010, carried out by the ITU (IMFIA et al., 2012; IMFIA et al., 2017). However, one respondent commented that though this information from the survey has been useful, it is today outdated, due to continuous change of the flood risk zone such as people moving away from the risk zone. In the final report for the ANII-project it is therefore noted that “updating the basic information on which the system is based can constitute a weakness of the system” (IMFIA et al., 2012, p. 124). Within the frame of the second project, the PROHIMET-project, the challenges regarding the sustainability of the data have been addressed by incorporating data on people, housing and infrastructure from other institutions that are “responsible for the management and updating of the data,” (IMFIA et al., 2017). Two of the respondents commented on the possibilities of the updated spatial information system, which has recently been implemented. One respondent noted:

> “All social and geographic data has been included, that is the age of the people in the flood zone, the sex of the people in the flood zone, if there are people with disabilities, if there are poor people, if there are women who are pregnant. A complete and updated database has been incorporated […]”

Furthermore, the other respondent added:

> “We want to know who the people living in these areas are before the flood occurs.”

The second element, the monitoring and warning service, is provided by the technological capacity developed by the IMFIA. It was noted by four of the respondents that a challenge regarding this second element is to transfer the operation of the system from the university to national authorities. As mentioned by one respondent, “a weakness of the system is its dependency of a team continuously available, with the capacities to advice the CECOED and handle a break-down of the system.” According to another respondent, “the CECOED does not have any person with a background in hydrology and hydrodynamics, and they do not have sufficient technological training to understand the system fully.” Officially, after Project-ANII ended in 2017, the IMFIA does not have any responsibilities regarding the EWS in Durazno, although the operation of the tool has not been transferred yet. Therefore, as noted by several of the respondents, the IMFIA and the CECOED continue working together on an “informal basis,” where it is possible for the CECOED to contact the IMFIA anytime during day or night, whenever support is needed, to interpret the information from the web site. In order for an EWS to be sustainable, all roles and responsibilities of all organizations generating and issuing warnings should be established and mandated by law (UNISDR, 2006). Within the frame of the ANII-project, the tool was therefore supposed to have been transferred to a national body, defined by the national institutions, the DINAGUA, the INUMET and the SINAE.

Nevertheless, as one respondent put it, due to “incapacities” of the institutions, the transfer of the tool was not realized before the project had terminated. According to the national emergency director, SINAE is now responsible for financially supporting a new agreement that will finalize the transfer, which is hoped to be completed in 2018.

For the third element, dissemination and communication, the respondents stressed that there is some mechanism in place to communicate and disseminate alerts to the people at risk, but that it needs to be further developed in the future. Four of the respondents explained how the information from the tool developed by the university is disseminated from the CECOED to the people at risk to activate evacuation. When the CECOED observes an alert on the web page, i.e. a different color than green, the first step is to convene the CDE that will gather in a meeting, where they will decide whether to begin an evacuation, how many should be evacuated, where the shelter should be located, how to assist medical care needs etc. When the CDE decides to initiate an evacuation, they distribute a press release with information about the predicted river level in order for the people, who live within the area that the flood will reach, to evacuate. According to one of the respondents, an example from a press release could be that “all people living in the area that the flood reaches when the river level reaches 10 meters have to evacuate.” The evacuation takes place in stages, and every day a new press release is distributed with a new river level. As one respondent noted:

> “We communicate to the community through the media, through television, through radio. Every day we update them with new information on who should be evacuated in which zones. We also ask them to evacuate during the day and not during the night.”

Two of the respondents stressed that the communication reaches the entire population at risk. According to one of them, the press release is distributed on all social media and to all media in the department of Durazno as well as national media, and therefore they “do not need to worry that it will not reach the entire population.” The other respondent emphasized that although some older people are not used to technology and will not receive the alert through social media for example, they will receive the alert in any case. According to him, since older people generally do not live alone in Uruguay, but together with their families, they will be notified about the alert through them.

Thus, there is some mechanism in place to communicate to the people and to disseminate the alert. However, several of the respondents questioned if it is sufficient to use the media for the dissemination of alerts and emphasized the need “to continue improving the communication”. The national director of SINAE mentioned the opportunity of communicating directly with the people using cell phones since almost everybody in Uruguay has a phone. Initiatives towards this end are already being taken, and soon a tool to send text messages to all people within one kilometer of an emergency will be implemented in Uruguay, with Durazno being one of the first departments.

According to UNISDR (2006), a communication system should be “two-way and interactive to allow for verification that warnings have been received.” The press release is only a one-way communication. However, in addition to the press release, it was noted that a group of volunteers also help with the communication between the authorities and the people. For instance, if a person does not want to leave their house when they have to evacuate, the volunteers will “talk with them and try to convince them.” In case that is not possible, the volunteers will pass the information on to the authorities in order for them to help with the evacuation. The inclusion of volunteers in this two-way type of communication is however still an “initial process”, “a first step” as stated by a respondent.

Finally, the focus on the fourth element, response capability, has until now been very limited according to the national director. However, two of the representatives from the CECOED mentioned that some measures have been taken. First, it is mentioned that flood risk is part of the curricula in the schools, although it is to a limited degree. One respondent remarked that in general “public awareness and education campaigns in order to raise awareness about flood risk are limited due to a lack of budget.” Nevertheless, the other respondent noted that some training courses have been conducted by international organizations such as the Office of US Foreign Disaster Assistance and the Adventist Development and Relief Agency in order to raise awareness on the EWS. One respondent noted that you have to “put yourself in the place of the evacuee.” It is not given that the people living in the flood zone know at what river level the flood will reach their house, if they have never been told. Nevertheless, according to the respondent the training has taught them at what level to evacuate, and therefore today “most of the people living in the flood risk zone, who have experienced previous floods, already have the understanding that at so many meters, the river will reach their house and they have to evacuate.”

Thus, the risk knowledge and monitoring and warning service elements are present through the technological decision-making tool, and the two other elements, dissemination and communication and response capability, are also present, although it is to a limited degree.

5.1.3 Participation

A people-centred EWS relies on the direct participation of the people at risk. However, three of the respondents noted that the approach to early warning in Durazno is generally top-down. Since the system has been developed more as a decision-making tool to the authorities, the authorities decide when to share what information to the people and when they should evacuate. Furthermore, as pointed out by a respondent, the people are not engaged in risk and vulnerability assessments in such a way that they "feel part of the development of a solution to the floods and not only as part of those affected by the problem." It is therefore noted that "until now, the system has not allowed the people to feel ownership."

It was suggested by one of the respondents that in order for the people to be more closely involved with the system in the future, the information from the decision-making tool should be better shared with the population immediately and not just in stages through the CDE. However, another respondent pointed out that it would be challenging to make the tool open to the public, supporting his claim with an example:

> "Once, it happened that a journalist took a picture of the link to the web page of the system. Then, one day when the system was calibrating, it wrongly showed that a flood, corresponding to a river level of 15 meters, would occur. For you to have an idea, 12 meters is a chaos, so you can just imagine 15 meters. It is more than the entire city. As the journalist had the link to that information, he spread it to the entire population. It was a chaos for the authorities to deal with. So early warning should be handled by the CECOED and the CDE.

In addition to this challenge of engaging people directly with the support tool, another challenge regarding the reliability of local knowledge was mentioned. According to one respondent, there are people "who have lived at the Yi River for 40 years, who have been fishermen in the river, who know the river." The respondent noted that this sort of knowledge is something that needs to be respected, but that "due to climate changes the behavior of the river today is unpredictable without a technological and scientific tool."

5.2 Impacts of the Technological Tool on Decision-Making for Emergency Planning

The interviewed respondents expressed that the decision-making process regarding emergency planning in Durazno had improved substantially with the implementation of the decision-making tool.[1] Two impacts of the tool on decision-making were identified to answer RQ2: time to plan and increase of social trust.

5.2.1 Time to Plan

All the respondents noted that a long lead time of the early warning between 36 and 72 hours has given the authorities the capacity to plan the response more accurately before the water arrives. Several of the respondents compared how the response was when there was no EWS with how the authorities respond to floods today. According to respondents from the CECOED and the CDE, the flooding in 2007 was a chaos in terms of organizing how to protect people, and it was just a "luck" that nobody lost their life. The river kept rising, and nobody knew how far it would grow and when it would stop. At the same time, it had started raining again, complicating the evacuation of people living in the flood zone. People were being evacuated with the water up to their waists. They had around 12,000 people evacuated, and the authorities did not know how long time they would need to be evacuated, where to locate the shelter outside the flood zone and how much food they would need. Other respondents noted that what the authorities did before having an EWS was to observe if it was raining, and if the river level as a consequence would rise. They would not begin the evacuation until they saw the river rising, meaning that people were often evacuated when the water had already reached their houses and sometimes during the night.

Today, due to the long lead time, the decision-making tool has allowed the CDE to start planning the response several days before the flood reaches Durazno. Using the tool, they now have time to warn people before the flood occurs and to evacuate them before the water enters their houses. They furthermore have estimates of which areas and how many people the flood is going to affect, improving the planning of provision of shelter and food. A respondent further noted that this allows them to work "in a state of cooperative peace", elaborating that when they are working under high

[1] It should be noted that the respondents refer to the decision-making tool with the term "EWS" as elaborated in the section on the perception of the scope of the EWS. However, in order not to confuse it with the general definition of an effective EWS, including all four essential elements, the term decision-making tool is used.

pressure, they do not have time to cooperate. When they have more time, "the gears start to move", and it allows them to remember successful measures they took during previous floods.

Several of the respondents also commented that time to plan better allows the CECOED to optimize the human and economic resources. One respondent for example noted that having people evacuated in a shelter is a costly affair, but that the decision-making tool allows them to optimize the time that people need to be evacuated. Furthermore, better planning results in a need for fewer vehicles and less external assistance, for example to support evacuation.

Because of the many improvements of the response planning due to the longer time frame, the respondents concluded that the tool serves as a fundamental measure to manage floods in Durazno today. As one respondent put it, "the system has changed the history of how the CDE deals with emergencies." If the tool did not work one day, it would be "to handle an emergency in blindness."

5.2.2 Increase of Social Trust

Social trust in the authorities that manage emergencies is fundamental for decision-making and risk communication to be effective (Cvetkovich, 1999; Wachinger et al., 2013). If the people at risk do not trust the information they receive from the authorities, they will not act on the authorities' requests. Six of the seven respondents agreed that one of the most important impacts that the decision-making tool has had on the work of the CDE and the CECOED is that the trust of the people in the authorities has increased.

According to two of the respondents, before having an EWS in Durazno the citizens did not trust the authorities. The authorities' response to floods was a chaos since they did not have any information on when and where the flood would reach, and consequently instead of listening to the authorities, the people would base their decisions on whether to evacuate or not on their own judgment and knowledge of the river. As mentioned by one respondent, the people would sometimes rationalize that "the flood did not reach me the last time, so it will probably not reach me this time either." Several of the respondents pointed out that over time the authorities have developed a high level of trust in the information from the decision-making tool, and as one respondent put it "this trust has transferred to the people." Today, if people are told to evacuate because the flood will reach their house, they will evacuate. Today, they trust the information that the CDE communicates to them.

Two reasons for the high level of trust that the citizens have in authorities and the information provided by the decision-making tool were identified by the respondents.

First, the communication between the CDE and the people was pointed out as a factor for the social trust. According to one respondent, they did not have a fixed way of communicating to the people before the EWS. They always “discussed how and what to communicate.” During a flooding today, they communicate new information to the people every day through the media.

Second, due to the many floods in Durazno during the last years, they have already gained a lot of experience with the tool. Since the implementation of the EWS in 2011, Durazno has suffered 12 floods. Therefore, they have already seen that the information provided by the tool is correct, elaborated by the respondent from the CDE:

> “The citizens trust us. Why? Because everything we have announced has been fulfilled. Therefore, the people know that if we tell them that the river will reach 10.5 meters and that the flood will reach their house, they know it will happen. In that way, we have gained their trust.”

Another respondent commented:

> “There is a strong social factor related to the EWS in terms of people leaving their houses when the committee tells them to evacuate. What they have gained is credibility, because when the committee communicates to the people, based on the information from the EWS, what is communicated happens.”

The people’s trust in the authorities has thus been developed over time as more experience has been gained with the EWS. When it was first implemented, the citizens did not trust the information according to several of the respondents. The first time the tool was used, the people would not believe it since it was just a few years after the chaotic flood in 2007, one respondent told.

5.3 Roles of the Technological Tool and Social Factors when Initiating an Evacuation

The technological tool for the EWS is developed as a decision-making support tool for the authorities in Durazno, particularly to improve evacuation planning. In order to answer RQ3, the section examines what role the tool plays in the decision-making process regarding evacuation and what other social and political factors are at play. It is demonstrated that (i) the authorities always use the technological decision-making tool due to a general high level of trust in the tool; (ii) this trust is dependent on experience with the tool; and (iii) the tool does not trigger evacuation since political-social factors regarding certainty of the alert and time people are outside their houses are taken into account.

5.3.1 Trust for the Adoption of the Technological Tool for Decision-Making

Almost all of the respondents pointed out that due to the trust that the authorities have in the system developed by IMFIA, it is always being used as a base for decision-making regarding flood evacuation. As one respondent from CECOED noted, all the officials in the CECOED are "permanently connected to the web page." The officials are monitoring the system all the time, and they always present all the information from the system to the CDE to base their decisions on. According to another respondent, the system is the "main factor" that the decisions are based on. It works "spectacularly." The engineers from IMFIA furthermore noted that the tool is being used in Durazno "in the way they hoped." The most important result for them is that the CECOED "has received the system positively." Also the representative from the CDE emphasized that the CDE generally has a high level of trust in the information given by the tool, and that it is always used for decision-making regarding evacuation for floods. However, as with the social trust that the people have developed in the authorities, it was noted by several of the respondents that the authorities trust in the tool is dependent on the experience they have gained with it. Specifically, the respondent from the CDE pointed out the importance of the length of time she has worked in the CDE:

> "I have been here for a long time, but there are also members of the committee that have been here for two years or for three years and have not experienced the whole process. Maybe I trust more, because I have seen the results over time. […] There is always somebody in the committee meetings exclaiming 'Really? It will be like that? Let us wait and see."

It was therefore suggested that in order "to make better use of the information" from the tool in the future for decision-making regarding evacuation, an opportunity would be to decrease the gap between the CDE and the tool. This would allow the members of the CDE to understand the tool better and not just through the CECOED, to evaluate the tool and to build a higher level of trust in it.

5.3.2 Social Factors in Decision-Making

Although the general agreement was that the technological support tool plays a fundamental role in the decision-making process regarding evacuation, several of the respondents emphasized that the tool does not "trigger" evacuation. One respondent indicated that the alert is generally received by the CECOED 48 to 72 hours before the flood occurs, but the evacuation is often initiated by the CDE much later. However, as one of the engineers said:

> "It might not be wrong that the CDE does not initiate the evacuation when they receive the alert from the CECOED, because they should value other factors as well such as economy, social aspects of the population, how long time people should stay outside their houses, health risks, and loss of school classes for the children. Thus, there are different components that are not only technological and hydrological. Obviously there are other factors beyond the EWS[2]."

The respondents from the CECOED and the CDE agreed with this view and commented that "the model does not make the decisions" and that it is "a political decision to evacuate since there is a political-social component that the program cannot perceive." One respondent elaborated:

> "It provides us with very very valuable information, but when the decision is made, it is *based* on the information, and it is not the direct *result* of the information. It is an important tool but the decision lies within the CDE."

Three social factors explaining why the CDE generally does not initiate an evacuation as soon as they receive the information from the CECOED were identified by the representatives from the CECOED and the CDE. First, the respondent from the CDE pointed out that they do not want to "warn people wrongly." The information on the web page is being updated every six hours, and they therefore often prefer to wait until they have more "certainty." According to two of the respondents, another factor contributing to the decision about when to initiate the evacuation is that the people's houses are "subject to looting," while they are evacuated. As one of the respondents commented, it is therefore important "to make every effort to minimize the time people spend outside their homes, but however evacuate people before the rain starts and not return them to their houses before it is safe." Extensive social science research on disaster behavior has classified looting during disasters as a common myth

[2] Note that in this case the EWS refers to the technological support tool for decision-making as defined in the final reports for the PROHMIT-project and the ANII-project.

(Quarantelli, 1994). Although it is therefore possible that such looting might in fact not occur, the people's fear for looting could also play a role in the reasoning for minimizing the time people are evacuated. One respondent noted:

> "If people are evacuated, and the river has still not risen after 3 to 4 days, they can make a revolution. Literally. Nobody wants to leave their homes. Their homes can be robbed."

In this perspective, the last factor identified by two of the respondents is that the authorities should be careful not to lose the trust of the people that they have gained with the technological decision-making tool. The respondents claimed that if the evacuation becomes a "mechanical act," where the people are being evacuated several days before the flood arrives, they will lose the trust in the authorities again. Therefore, as one respondent opinioned, evacuating 3-4 days before the flood occurs, although they already received an alert, "is very bad politics."

6 Discussion

This chapter discusses the main contributions of this thesis to the understanding of the integration of a technological tool in an EWS within a social context. Drawing connections to existing literature, it begins with a discussion of the extent of social aspects of the EWS in Durazno, further development of the social component in the future, and the local authorities' adoption of the technological tool. Subsequently, it is discussed whether lessons learned from the EWS in Durazno can be used in other contexts, and future research areas are proposed. Finally, recommendations for the local and national authorities within the SINAE structure are presented to further develop the flood EWS in Durazno in the future.

6.1 Social Aspects of the EWS

Literature on early warning emphasizes that an EWS needs to be viewed as a social process, in which technological components are embedded, in order to be effective. (Basher, 2006; Kelman & Glantz, 2014). The findings in this thesis suggest that the stakeholders in the flood EWS in Durazno acknowledge this view, stressing that the fundamental reason for having an EWS is social. Although when using the term 'EWS' the respondents generally referred to the technological tool, the results from this study show that if approached in a greater context, other components of social nature are in play to some degree in the EWS in addition to the technological tool. Specifically, two social aspects of the EWS emerged from the findings.

The first social aspect emerging from the findings is that in the decision-making process on when to initiate a flood evacuation, social factors in terms of minimizing the time that people spend outside their houses and certainty of the information to avoid false warnings are integrated in addition to the technological tool. This result reveals a contrast to the conventional view of an EWS as a linear chain from observation to the dissemination of an alert to the people at risk, instead indicating the presence of political and social factors before the alert is disseminated to the people. Understanding the EWS in a bigger context than the technological decision-tool as perceived by the respondents, a political-social decision-making component is thus integrated. This is in accordance with Kelman & Glantz' (2014) view that an EWS should always include decision-making.

An interesting finding related to this first aspect is a mutual acknowledgment by all stakeholders of the political-social component that cannot be captured by the technological tool. According to Parker

(2017), "hydro-meteorologists and hydraulic engineers who forecast floods sometimes not only confusingly refer to them also as flood warnings but genuinely *believe* that all that is necessary to avoid losses is to disseminate an accurate flood forecast" (p. 12). Although the forecasts indeed indirectly are referred to as flood warnings in terms of the technological tool being mentioned by the term 'EWS', the results show that the use of the tool is not believed to be sufficient to avoid an emergency, neither by the engineers nor by other stakeholders. The tool is developed for decision-making, and it is not expected that the tool should trigger response directly. It should however be noted that in the flood EWS in Durazno, the engineers are not the only core stakeholders, which they tend to be in EWSs (Basher, 2006). Although both the PROHIMET project and the ANII project were led by the IMFIA, the projects also involved the participation of other institutions, including the SINAE institutions. An important characteristic of an effective EWSs is close collaboration between many different types of organizations. This mutual acknowledgment by the respondents of a political-social component might therefore possibly be explained by inter-institutional collaboration between the engineers and the decision-makers.

Secondly, although it is hard to measure on a scale the extent of the integration of all the four essential elements of an EWS, in this study an attempt was made to examine whether all the elements are in place. In addition to the risk knowledge and monitoring and warning service elements, which are provided by the tool developed by the university, it has been shown that the two other elements also are present to some degree, bringing in a social aspect. For instance, a mechanism to communicate and disseminate an alert to the people at risk is established through the media and an initial step has been taken to integrate volunteers with the work of the authorities.

Although some social aspects are thus present, the findings emphasize that it is still to a limited degree. Until now, not enough focus has been given to all of the elements of an EWS, and especially the communication and dissemination and the response capability elements need to be further developed in the future to be an effective EWS. In this respect, an interesting question to raise is what influence the stakeholders' perception of the EWS as a technological tool has on the extent of the elements that constitute an effective people-centred EWS. It was noted by the national director of SINAE that the focus so far has been mainly technological, with essential components of a people-centred EWS being almost invisible, and that it is in this light that the stakeholders generally refer to the technological tool when using the term 'EWS'. Basher (2013) argues that the way the threat of a disaster is dealt with is fundamentally dependent on how the problem is framed, and therefore care is needed with terminology in DRM. It might therefore be possible that it is a two-way process in which the use of the term 'EWS' to denote the technological tool is not only caused by the technological focus of the EWS, as suggested by the national director, but also influences the approach of the EWS to deal with disasters, reinforcing the technological focus. If this is the case it would consequently be a necessity to broaden the general perception of the scope of the EWS to include all four essential elements within its social context to develop it into a truly effective people-centred EWS in the future.

6.2 Social Trust as a Basis for Further Development of the Social Component

The findings showed that the technological decision-making tool has increased the trust of the people at risk in the authorities. The increased social trust could be used as a basis for further development of the system into an effective people-centred EWS in the future.

The respondents' conviction that the trust of the people at risk in the authorities has increased as a result of the decision-making tool is not based on a survey conducted among the people, but on the observation that today the people act upon the information that the authorities communicate to them. This belief aligns with literature on the relationship between social trust, risk communication and individual preparedness. According to Wachinger et al. (2013), "trust in authorities is necessary to build up a social climate in which advice from the authorities will be taken into account in a crisis situation" (p. 1061). Cvetkovich (1999) furthermore notes that failures of risk communication initiatives can often be explained by the fact that "reactions to risk communications are not only influenced by message content, that is, what is communicated about risks of particular hazards. It is also influenced by trust in those responsible for providing the information" (p. 2). Therefore, a prerequisite for effective risk communication that the people at risk act upon is that the people trust the authorities.

It should be noted that trust is not only important for the communication regarding dissemination of an alert to the population at risk to activate individual action to respond to the hazard, i.e. to evacuate in the case of Durazno. On the other hand, trust is important in all areas of risk communication initiatives, including risk education and training programs to increase people's knowledge of how to react in case of a flood event. If the people do not trust the authorities, they will be less susceptible to training and education. In this light, the social trust that the authorities have already gained through the decision-making tool represents a vital opportunity if further maintained and promoted. To this end, a measure to be taken by the authorities could be to engage the population in participatory exercises, given that working together with the authorities has a positive effect on social trust (Wachinger et al., 2015). Literature stresses that if the authorities do not understand that they have to work with the people and not simply educate them as a public information exercise, transmitting messages from the authorities to the uninformed citizens, risk communication will fail and the people will lose their trust in the authorities (Cvetkovich, 1999; Twigg, 2003). Several respondents indicated that the approach to flood early warning in Durazno is top-down, not allowing the citizens to feel ownership, and several examples were provided to emphasize the challenge of engaging the people at risk. However, participatory engagement can take many forms, and as proposed by Kates et al. (as cited in Wachinger et al., 2015) many of such initiatives are "relatively unthreatening to implement." As pointed out by one respondent, although the spatial information system provides knowledge on vulnerability of the people at risk, the people themselves do not participate in the mapping of their vulnerabilities. A possible first step towards greater participation of people and promotion of the people's trust in the authorities could therefore be to involve the citizens themselves in the assessment of their vulnerabilities.

6.3 Adoption of the Technological Tool

The importance of the technological aspect within its social context should not be neglected, and rather than preclude this aspect it should be embraced and go hand in hand with social aspects. The findings of this study show that the authorities' use of the technological decision-making tool in Durazno has had widely positive impacts on decision-making for emergency planning. The tool plays a vital role in the decision-making process regarding evacuation, and though not triggering evacuation it is always being used. In current research on decision-makers' adoption of technology in DRM, the focus of trust of the tool by the decision-makers is limited. Some research, however, demonstrates a relationship between a lack of implementation of technological measures and a lack of trust (UNISDR, 2009a), corresponding to the findings from this study that the authorities always use the tool due to a high level of trust in the information provided by the tool.

Basher (2003) notes that, decision-makers will "readily accept scientific and technological information when it is understandable, relevant to the interests of those involved, and affordable" (p. 13). It could be questioned whether the decision-making tool in Durazno is being used because these three requirements are fulfilled. First, affordability of the tool has not been touched upon in this study, and this requirement will therefore not be discussed. Second, several significant improvements of decision-making with the implementation of the tool have been demonstrated, and the tool can therefore be considered to be of high relevance for the authorities. Finally, the understandability of the tool for the CECOED and the CDE respectively will be discussed in the following.

As the findings reveal, the CECOED is reliant on technological advice to understand and interpret the information from the tool. So far an informal communication with the IMFIA has enabled the CECOED to understand the technological information. It is recognized that successful communication between scientists and decision-makers is necessary to improve decision-makers' understanding of technological tools and to overcome the challenge of integrating technology into policy (Aitsi-Selmi, 2016; UNISDR, 2013). Therefore, in order for the technological information to continue being understandable for the CECOED in the future, it is important that the CECOED continues to have access to technological advice after the transfer of the operation of the tool to national authorities. On the contrary, how well the tool is understood by the members of the CDE is more questionable. The CECOED serves as a link between the tool and the CDE. As indicated by a respondent, the distance from the tool to the CDE is therefore longer, resulting in less knowledge or understandability of the tool by new members of the CDE. An improved communication directly between the engineers and the CDE should therefore be pursued to increase the members' understanding of the tool and trust in it and thereby willingness to use the tool even more than today.

6.4 Lessons Learned to Inform Other Cases

This study has attempted to put light on the integration of a technological tool in an EWS within a social context through a single case study from Durazno in Uruguay. An interesting issue to address is whether other contexts than Durazno can learn from the findings of this study to inform the developments and improvements of new or already existing EWSs in the future.

As elaborated in the methodology chapter, the study is not attempting to generalize its findings to a broader context, but contribute to the understanding of the integration of technological tools and social aspects in EWSs on a micro-level. This being said, the case of the EWS in Durazno was selected for its representativeness as a typical EWS based on a technological forecasting model (Yin, 2009). Therefore, it is argued as in accordance with Yin (2009) that learning outcomes from this study regarding how to integrate a technological forecasting tool in an EWS within its social context can be extended to other similar cases to some degree.

Care should be taken when identifying similar cases. Although the EWS in Durazno is a typical flood EWS based on a technological tool, different characteristics of contexts might have an influence on how the technological tool is integrated. For instance, it is possible that the informal communication informing trust between stakeholders, revealed in this study, are due to specific characteristics of Uruguayan culture that are not necessarily present in other cultural contexts. Furthermore, DRM in Uruguay follows a principle of decentralization. It is therefore unlikely that lessons learned from this study regarding how a technological tool can improve emergency planning on a local level can inform the development or improvement of an EWS within a centralized governance structure.

Undoubtedly, the most similar cases to the EWS of Durazno are other flood EWSs in Uruguay based on the same sort of technological decision-making tool, within the same cultural context and legal framework. An equivalent decision-making tool to support the CECOED Artigas in the north of Uruguay has already been implemented as part of the ANII-project, and further support tools are planned to be developed in the departments of Treinta y Tres and Río Branco in the near future. The lessons learned from this study do not only represent an opportunity for further development of the EWS in Durazno but also for the development and improvement of other similar EWSs in Uruguay.

6.5 Recommendations

The following are recommendations for the local and national authorities within the SINAE structure in order to improve the integration of the technological decision-making in the flood EWS in Durazno within its social context in the future.

(i) Promote a people-centred understanding of the EWS to include all of the four elements for an effective EWS: risk knowledge, monitoring and warning service, dissemination and communication, and response capability. Currently, the general perception of the scope is that the EWS only includes the technological decision-making model. To visualize the importance of the social context that the EWS operates within, the EWS should be framed in more holistic terms.

(ii) Further develop the dissemination and communication element and the response capability element of the EWS.

  a. Currently, the CDE Durazno disseminates alerts and communicates to the population at risk through the media. Further work should be done to make the communication system two-way, allowing the people at risk to communicate back to the authorities.

b. Greater efforts should be made to train and educate the people at risk in order for them to know how to react to an alert.

(iii) Maintain the trust of the people that the authorities have gained with the decision-making support tool by promoting participation of the people at risk. Trust in the authorities is necessary for successful risk communication and therefore serves a prerequisite for effective training and education of the people at risk. Engaging the people at risk has a positive effect on trust, and therefore a participatory bottom-up approach to early warning should be promoted in contrast to the current top-down approach.

(iv) Strengthen the understanding of and trust in the decision-making support tool by the CDE by promoting a direct communication between decision-makers and technologists. Although the trust of the members of the CDE is generally very high, it could be strengthened even more by increasing their understanding of the decision-making tool in order to enable an improved use of the tool.

6.6 Reflection on Future Research

Since the technological tool to predict floods in Durazno has been developed as a support tool for decision-makers, the focus of this study was to examine the integration of the tool within a social context from the perspective of the authorities and the scientific developers. In the future, another interesting approach would be to examine the same topic from the perspective of the people at risk. This study has shown that the technological decision-making tool plays a significant role for the decision-makers, and that it is always being used in the decision to initiate an evacuation. However, the purpose of a people-centred approach to an EWS is to enable those at risk to prepare and act appropriately to reduce the possibility of harm or loss. Therefore, it is essential that not only the decision-makers and the technological developers find the tool successful but also the people at risk. An interesting aspect would, for example, be to examine whether the people at risk agree with the claim of the respondents in this study that the level of social trust has increased with the implementation of the tool.

7 Conclusion

The conventional view of an EWS is that it is an engineering solution of a monitoring and warning system, following a linear chain from observation through warning generation to the dissemination of the warning to the people at risk. This view is pure technological, ignoring social and human aspects. The need to view an EWS as a social process with a strong focus on the people at risk is therefore recognized. To contribute to the understanding of the integration of technological tools in a social context, a representative case study was conducted of a flood EWS in Durazno in Uruguay. From the perspective of the authorities and engineers, it was examined how far a technological support tool for decision-making is included in a social context.

The study revealed that the general perception of the scope of the flood EWS in Durazno is purely technological, only incorporating two of the essential elements of an effective people-centred EWS: risk knowledge and monitoring and warning service. The two other essential elements of an effective EWS, dissemination and communication and response capability are also present to some degree although generally not assumed to be an integrated part of the EWS. Nevertheless, it is still to a limited degree, and further work needs to be done in the future to develop these two elements and thereby visualize more the human and social aspects of the EWS. The technological framing of the EWS might reinforce the current technological focus on the EWS, and therefore a broader perception of the scope of the EWS should be promoted to integrate all essential elements of an effective EWS.

The study furthermore revealed that the impacts of the technological tool on decision-making regarding emergency planning for floods have been positive. The long lead time of the support tool has allowed the local authorities to plan for response to flooding before the water arrives to people's houses. This in turn has increased the trust of the people at risk in the authorities since over time they have experienced that the information provided by the tool is correct.

Finally, it was shown that the role of the technological support tool is significant in the decision-makers' decision to initiate a flood evacuation. The authorities' level of trust in the tool is generally very high, and therefore the tool is always used. Nevertheless, this trust could be strengthened even more together with the decision-makers' understanding of the technological tool through an improved communication directly between the decision-makers and the developers of the tool. Despite the important role of the support tool, it does not trigger evacuation. The decision to evacuate is political, and several political and social factors in terms of certainty of the information from the tool and minimizing the time that people spend outside their houses are integrated alongside the technological tool. This finding implies a political-social decision-making component, contrasting the conventional linear view on an EWS as a chain directly from observation to the people at risk.

It can be concluded that the technological support tool is very successful from the point of view of the authorities, and to a limited degree, that it is embedded in its social context. Nevertheless, to make it a truely people-centred EWS, the social aspects of the EWS need to be further developed. To this end, a participatory bottom-up approach to early warning to maintain the trust of the people that the authorities have gained with the technological support tool represents a great opportunity.

The lessons learned from this study are not only applicable for the further development of the EWS in Durazno. Being selected as a representative case of a typical EWS based on a technological forecasting tool, the learning outcomes can be extended to other similar cases. Specifically, the lessons learned represent an opportunity to inform the development of other similar flood EWSs in other cities in Uruguay.

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Appendices

Appendix 1: Interview Guide for the CECOED Durazno

Personal information:

- For how long have you been working in the CECOED?
- What is your educational and professional background?
- Can you briefly tell me what your job entails in relation to the flood EWS in Durazno?

Background of EWS:

- How would you define an EWS?
- In your opinion, why was a flood EWS needed in Durazno?

Impacts and role of tool:

- How do you think that emergency planning in Durazno has been impacted with the decision-making support tool?
- How is the tool used by the CECOED?
- In your opinion, is the technological tool used sufficiently?
- Do you think that there are any challenges for the adoption of the tool in the CECOED?

Social aspects:

- According to UNISDR, an EWS should be people-centred and integrate social factors, and therefore not be a pure technological solution. Do you think that the Flood EWS in Uruguay integrates social factors and how?
- What role does the spatial information system, developed by the ITU and incorporated in a GIS, play in your work regarding emergency planning for floods?
- Do you perceive the spatial information system to be part of the EWS?
- How is an alert from the decision-making tool disseminated to the people at risk? Is this communication mechanism sufficient?

Future:

- What are the opportunities of the EWS in the future in your opinion?

Appendix 2: Interview Guide for the CDE Durazno

Personal information:

- For how long have you been a member of the CDE?
- Can you briefly tell me what your role as the representative of the Ministry of Social Development in the CDE entails?
- What is your role in relation to a flood warning in Durazno?

Background of EWS:

- How would you define an EWS?
- In your opinion, why was a flood EWS needed in Durazno?

Impacts and role of tool:

- How do you think that emergency planning in Durazno has been impacted with the decision-making support tool?
- How do you use the information provided by the CECOED, based on the tool developed by the university to make decisions regarding evacuation of the population in Durazno?
- In your opinion, is the information provided by the CECOED used sufficiently?
- What do you think are the driving factors for the adoption of the tool?
- Do you think that there are any challenges for the adoption of the tool in the CDE?

Social aspects:

- According to UNISDR, an EWS should be people-centred and integrate social factors, and therefore not be a pure technological solution. Do you think that the Flood EWS in Uruguay integrates social factors and how?
- What other factors than the information provided by the decision-making tool have an influence on the decision to initiate a flood evacuation in Durazno?
- How is an alert from the decision-making tool disseminated to the people at risk? Is this communication mechanism sufficient?

Future:

- What are the opportunities of the EWS in the future in your opinion?

Appendix 3: Interview Guide for the IMFIA

Personal information:

- For how long have you been working for the IMFIA?
- What is your educational and professional background?
- Can you briefly tell me what your role in relation to the flood EWS in Durazno entails?

Background of EWS:

- How would you define an EWS?
- In your opinion, why was a flood EWS needed in Durazno?
- In your opinion, what are the roles and responsibilities of IMFIA in relation to the Flood EWS today?

Impacts and role of tool:

- How do you think that emergency planning in Durazno has been impacted with the decision-making support tool?
- Do you believe that the tool is being used sufficiently as a base for decision-making regarding floods?
- Do you think that there are any challenges for the adoption of the tool by the local authorities?

Social aspects:

- According to UNISDR, an EWS should be people-centred and integrate social factors, and therefore not be a pure scientific solution. Do you think that the Flood EWS in Uruguay integrates social factors and how?
- Do you perceive the spatial information system to be part of the EWS?

Future:

- What are the opportunities of the EWS in the future in your opinion?

Appendix 4: Interview Guide for the National Director of SINAE

Personal information:

- For how long have you been working as the national director?
- Can you briefly tell me what your job entails?

Background of EWS:

- How would you define an EWS?
- In your opinion, why was a flood EWS needed in Uruguay?
- What has been the role of SINAE in the implementation of the Flood EWS in Durazno?
- What is the role and responsibilities of SINAE in relation to the Flood EWS today?

Impacts and role of tool:

- It seems like the Flood EWS has been successfully received by the CECOED in Durazno. A common challenge worldwide is to transform scientific and technological tools into practical decision-making. What do you think are the driving factors that enable the adoption of the decision-making tool in Durazno?
- What do you think are the challenges for the adaptation of the Flood EWS on a local level in Durazno?

Social aspects:

- According to UNISDR, an EWS should be people-centred and integrate social factors, and therefore not be a pure scientific solution. Do you think that the Flood EWS in Uruguay integrates social factors and how?

Future:

- The projects related to the flood EWS have all finished, and therefore IMFIA does not have any formal responsibility anymore regarding the decision-making tool. How does SINAE plan to maintain the EWS in the future?
- What are the opportunities of the EWS in the future in your opinion?

Appendix 5: List of Project Reports

List of reviewed project reports. The bolded reports were identified relevant for the focus of this study.

Document Name	Organizations	Year
Proyecto Piloto PROHIMET: Alerta Temprana para la Ciudad de Durazno ante las Avenidas del Río Yí	**IMFIA, ITU, DINAGUA, Durazno department council, CECOED Durazno, UTE, MGAP, SINAE, PROHIMET & DNM**	**2012**
Steps to extend the Early Warning System of Durazno City to the Cities of Artigas and Treinta y Tres in Uruguay	WMO & IMFIA	2016
SATI-UY: Sistema de Alerta Temprana para Previsión de Inundaciones	**IMFIA, ITU, DINAGUA, SINAE, INUMET, Artigas department council, Durazno department council, CECOED Artigas, & CECOED Durazno**	**2017**

Appendix 6: List of Laws

List of reviewed laws reports. The bolded laws were identified relevant for the focus of this study.

Name	Number	Year
Ordenamiento Territorial y Desarrollo Sostenible	18.308	2008
Decentralización Política y Participación Ciudadana	18.567	2009
Sistema Nacional de Emergencias	**18.621**	**2009**