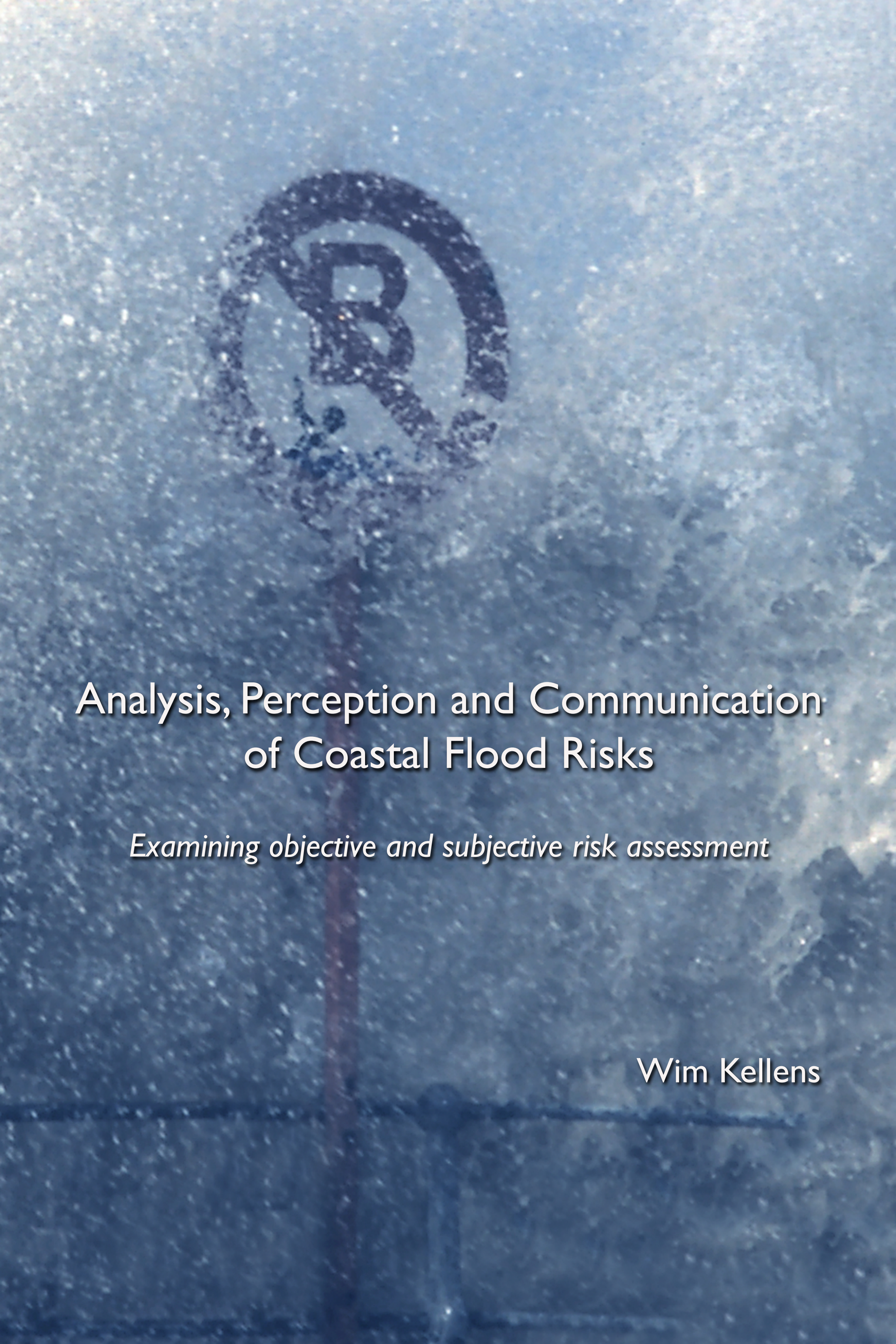

Analysis, Perception and Communication of Coastal Flood Risks

Examining objective and subjective risk assessment

Wim Kellens

ANALYSIS, PERCEPTION AND COMMUNICATION OF COASTAL FLOOD RISKS

Examining objective and subjective risk assessment

ISBN: 978-94-90695-82-8
Legal deposit: D/2011/12.134/32
NUR: 900/905/943
Printed in Belgium by University Press, Zelzate

Cover photo: Eric Kellens

The research reported in this dissertation was conducted at the CartoGIS research unit, Department of Geography, Faculty of Sciences, Ghent University, and funded by the Research Foundation – Flanders (FWO Vlaanderen).

UNIVERSITEIT GENT

Factulty of Sciences

Department of Geography

Analysis, Perception and Communication of Coastal Flood Risks

Examining objective and subjective risk assessment

Dissertation submitted in accordance with the requirements for the degree of Doctor of Sciences: Geography

Analyse, Perceptie en Communicatie van Overstromingsrisico's in Kustgebieden

Onderzoek naar objectieve en subjectieve risicobeoordeling

Proefschrift aangeboden tot het behalen van de graad van Doctor in de wetenschappen: Geografie

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Failure is not an option.

Gene F. Kranz, Flight Director during Apollo 13

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PREFACE

The cover photo of this book is full of action and denotation. A big wave hits the coastal front and partially hides a *no swimming*-sign. It doesn't matter, no one would be thinking of going for a swim under such conditions. Yet, this photograph betrays the presence of at least one person facing this danger. The photographer.

My dad took this picture on the Belgian coast in the early nineties. I stood just behind him. As a young kid, I was mainly busy struggling against the furious wind. I honestly can't remember much more from this trip, but it sure was an intense adventure. I like to believe this event unconsciously triggered my interest in storm surges and flood hazards. For a long time, the photo on the cover has thus been the herald of this dissertation.

Now, after four years of academic effort, I can look back on a difficult yet rewarding experience with many highlights and pleasant collaborations. True to tradition, I take the opportunity here to spotlight some people who played a small or a large role in the realization of this dissertation.

First in the row is my supervisor Philippe De Maeyer. As head of the Department of Geography, Philippe succeeds in the dashing exploit of managing the Department while teaching several courses, overseeing numerous projects, and supervising various PhD students. I am indebted to Philippe for pulling me in at the Department after my graduation, for encouraging me in striving for a PhD grant, for giving me the confidence and liberty to explore various research fields and for the support in making contacts and building up a network in the domain of flood risk.

Throughout this study, I have come across two persons who stand out from this network. First is Ruud Zaalberg, whom I got to know at a conference in Zürich in 2009. From the very first acquaintance, I was impressed by Ruud's statistical knowledge and insights. I thank Ruud for initiating me into the art of regression and path analysis, and for challenging my scientific thinking. Second is Teun Terpstra, to whom I owe great help in exploring the domains of risk perception and social science. I especially retain good memories to our brainstorm session in Delft and to the pleasant dinner on the 'student's market' in Den Haag.

I would further like to express my sincere gratitude to Tina Mertens and Kathy Belpaeme for reviewing and improving the questionnaires, and to

Wouter Vanneuville for the the invaluable aid and the helpful suggestions along the way. At the institutional level, I thank Flanders Hydraulics Research for introducing me in the study field of flood risks and for putting abundant data and know-how at my disposal.

Many thanks go to the colleagues of the Department of Geography, in particular to my cordial office mate Tijs Neutens, as well as to Els Verfaillie, Pieter Deckers, Ellen Meire, Kristien Schelfaut, Johan Reyns, Veronique Van Acker, Kristien Ooms, Bart De Wit, Valerie Vanopbroeke, Nathalie Van Nuffel and Marjanne Sevenant. I also acknowledge the excellent administrative assistance of Helga Vermeulen. Not only does she take care of the ins and outs of the Department, she is also a genuine listener and a wonderful counsellor, stand to give well-intentioned advice.

An extra word of gratitude goes to the colleagues who helped me distributing thousands of letters in the streets of Oostende. Eline, Els, Lisa, Lander, Matthias, Ruben and Tijs, it was probably not the most challenging task you ever did, yet you were all enthusiastic from the very first minute (or was it because of the lovely weather?).

In addition to the academic support above, I have received evenly important support from my family and friends. Thank you mom and dad, Liesbeth and Lillo, Karel and Annemie, and Tine. I have deeply appreciated your backing, your concern and your guidance during the past four years. I also extend words of thankfulness to my grandparents, who have always supported me in the background. Many thanks as well to my *geo*-friends and my old school companions for giving me the right distraction at the right time.

I have left one person to acknowledge. Marijke, thank you so much for your unconditional support, encouragement and understanding. Thanks for the numerous motivation chats, which have put me back on track, time and time again. Your contribution to this piece of work goes beyond words, and yet is present on every single page. Luckily, the past four years have been far more than just this PhD. Not only did we get married, we have built up a joyful life in Sint-Niklaas, and we are now on the verge of becoming mom and dad. I am thrilled to embrace that wonderful new life.

Ghent, August 7, 2011

Floods are 'acts of God',

but flood losses are largely acts of man.

Gilbert F. White (1911-2006)

1 INTRODUCTION

February 28, 2010. A heavy storm surge lams into the west coast of France. Meteo France observes alarming wind speeds and increasing water levels along the coasts of the Vendée and the Charente-Maritime departments. Despite these observations, a flood alarm remains forthcoming, let alone a major evacuation of the coastal area. And yet, the combination of high wind speed, wind direction and long storm duration produces alarming water levels. Within a few hours time, the seawall breaks at several places. The subsequent flood results in 53 fatalities and € 1,5 billion assured damage (Kolen *et al.*, 2010).

This storm depression, known as Xynthia, triggered substantial questions about coastal safety in France. In the vicinity of Aiguillon-sur-Mer, where 25 people fell victim, dike age goes back to the Napoleonic time. According to State Secretary Chantal Joanno, about 1,000 km or 10% of the French dikes are in poor condition. Xynthia also opened a touchy polemic about coastal urbanization, since approximately 100,000 houses were built in flood-prone areas during the last decade (Garnier and Surville, 2010). But most importantly, this storm showed that the inhabitants were insufficiently informed and prepared for such a disaster. There were no flood alarms, nor evacuation procedures. People were surprised by the quick-rising water and did not know how to respond. In addition, the storm occurred at night when many houses and bungalows had their electric roll-down shutters down. Due to the floods, a regional power failure transformed these roll-down shutters into a fatal trap (Kolen *et al.*, 2010).

Shortly after the Xynthia storm, the debate on coastal safety and coastal urbanization expanded to other North Sea countries. Economist Geert Noels opened the debate in Belgium by proclaiming that the Belgian coast would not withstand a storm such as Xynthia (De Standaard, March 2, 2010). Noels referred to the outcomes of the Master Plan for Coastal Safety (MPCS; Agency for Maritime and Coastal Services – Coastal Division; 2007-2011), which are available to the public on the Internet and which indicate that a major storm surge may cause thousands of casualties and billions of Euros material damage. Although this information was already available on the Internet for some time, Noels' statements created consternation among the public. While his message was slightly overstated by the selection of MPCS outcomes (that is, (i) he only mentioned the outcomes of a 'worst-case scenario', being a storm surge with a probability of 1 in 17,000 years, and (ii) he did not mention the on-going research and the planned defence improvements on the Belgian coast), the subsequent media controversy revealed one particular aspect: the general public seems insufficiently informed about the possible impacts and consequences of a severe storm surge on the Belgian coast.

This dissertation focuses on the management of flood risks on the Belgian coast, with attention to the analysis, perception and communication of these risks. In particular, it examines two approaches in flood risk management, namely objective and subjective risk assessment. Whereas objective refers to technical risk methods, subjective deals with the public's judgment and awareness of flood risks. Through the use of geographic information systems and two extensive surveys, various quantitative analyses are conducted to determine and compare objective and subjective risk assessments. In addition, this dissertation considers the interaction between risk perception and the public's need for information. The end goal of this research is to present valuable insights that could ameliorate risk communication and consequently improve the public understanding and awareness of coastal flood risks.

This introductory chapter starts with a general background to the objectives of this dissertation. Attention is given to the definition of risk and the management of flood risks. The distinction between objective versus subjective flood risk assessment is then discussed, as well as developments in risk perception and risk communication research. Background information is also provided regarding the vulnerability of coastal areas in general and the Belgian coast in particular. Finally, the objectives and research questions of this dissertation are presented and the following chapters are outlined.

1.1 Background

1.1.1 The meaning of risk

Risk is an artificial construct. It cannot be seen nor sensed, and yet, people have always attempted to judge and control the risks they are facing. As Renn (1998a) acknowledges, talking about risks is a delicate issue, since there is no commonly accepted definition for the term 'risk', neither in the sciences nor in the public understanding.

Numerous definitions of risk have been suggested throughout the years. Crighton (1999), for example, defined risk as the probability of a loss, depending on hazard characteristics, exposure, and vulnerability. Helm (1996) for his part defined risk simply as the product of the probability of a hazard and the consequences or losses of this event. Although Helm admitted that this product is not sufficient in itself to fully describe the real risk, he claimed that it provides an adequate basis for comparing risks or making resource decisions. To date, Helm's definition has been adopted in many other risk studies and analyses. Smith and Petley (2009), for example, describe risk as 'the probability of a hazard occurring and creating loss'.

The above-mentioned definitions all have in common that risk is a quantifiable concept, which is determined by its statistical probability and its consequences. While this approach makes it possible to compare risks, important information is lost in the process. For instance, regular flooding with limited consequences and exceptional flooding with huge consequences (such as the Xynthia storm) may be equal in terms of risk, though in practice they differ significantly: individuals and societies may be quite able to cope with the first type of floods, but not with the second (Mostert and Junier, 2009). Risk can therefore also be seen as a qualitative and social construct in which human viewpoints and preferences are considered (Luhmann, 2005). In this regard, Renn (2005) proposed a more generic definition of risk: 'risk is an uncertain consequence of an event or an activity with respect to something that humans value'. Recently, the definition of risk has been standardized in the ISO 31000:2009 as 'the effect of uncertainty on objectives' (Purdy, 2010). The contrast between a quantitative and qualitative approach reflects an ongoing debate between physical and social scientists, which is also known as the 'realist versus constructivist' debate (Renn, 1998b) or the 'objectivist versus subjectivist' debate (Slovic, 2000). Section 1.1.3 discusses this dual nature in more detail.

1.1.2 Managing flood risks

Risks occur in a variety of types and forms, and numerous authors have attempted to categorize risks. Table 1-1 summarizes two popular distinctions, based on the frequency of occurrence (Hewitt, 1997) and the type of hazardous agent (Renn, 2005). Regarding frequency of occurrence, Hewitt distinguishes between routine risks, which are associated with dangers that seem ever-present in daily life, and extreme risks, which are linked with threats that can overwhelm whole communities. Flood hazards are generally induced by natural forces (heavy rainfall, windstorms, etc.) and they mostly occur as extreme risks, implying that their probability of occurrence is low, but their consequences might be considerable. Worth mentioning is the distinction between risk and hazard. Whereas risk implies the probability of occurrence, a hazard can be described as any event having the *potential* for harm or other consequences of interest (Basic, 2009). Hazards become risks when consequences of interest are expected. For instance, a flood hazard becomes a flood risk when people are residing in the flood-prone area (Renn, 2005).

Table 1-1 Classification of risks according to their frequency (Hewitt, 1997) and hazardous agents (Renn, 2005)

Hazardous agents	***Routine risks***	***Extreme risks***
Physical	*Noise*	*Fire*
Chemical	*Pollutants*	*Toxic substances*
Biological	*Bacteria, viruses*	*Epidemic*
Natural forces	*Storm winds*	*Earthquakes,* ***floods***
Social-communicative	*Violence*	*Terrorism*
Complex	*Food*	*Nuclear*

Flood hazards are traditionally classified into three types: river, flash and coastal (Berz *et al.*, 2001). River floods are probably the best studied type of flood hazards. They are caused by the overflow of river embankments due to severe rainfall or snow melting (Bronstert, 2003). Related to river floods are flash floods, which occur after local high-intensity rainfall, leading to a rapid raise of water levels. They generally appear in mountainous areas and are very difficult to predict well in advance (Wagner, 2007). The third category is coastal flooding, which is usually caused by (extreme) high water levels due to wind storms and low atmospheric pressure, whether or not combined with an astronomical high tide. Storm surges are responsible for most of the worldwide loss of life from coastal floods (Smith and Petley, 2009). A rare but well-known type of coastal flooding are tsunamis, a series of large waves generated by sudden displacement of seawater, caused by an earthquake, a volcanic eruption or a submarine landslide (Jonkman, 2007). Besides these three classic types of flood risks, other flood hazard types have been defined, such as groundwater flooding (Kreibich *et al.*, 2009), sewage flooding (Arthur *et al.*, 2009), etc.

The management of flood hazards has long been restricted to a flood control approach, which implies a focus on complete prevention against a certain water level. This approach resulted in continually heightened levees and seawalls, without attention for the area that is to be protected from flooding (Broekx *et al.*, 2011). Since the 1990s, risk-oriented methods and risk analyses are gaining more and more attention in the field of flood hazards. By quantifying flood probabilities and considering possible consequences, the risk-oriented approach allows the evaluation of mitigation measures and consequently the optimization of investments. It also enables (re-)insurance companies, municipalities and residents to prepare for disasters (Apel *et al.*, 2009).

Just as risk is difficult to define, several definitions have been suggested for (flood) risk management. A good definition has been suggested by Kaiser and Witzki (2004): 'Flood risk management comprises the articulation of goals and the construction of strategies which lead to a decision about the demand of practices and the implementation of concrete measures to mitigate the adverse effects of flood hazards'. Schanze (2007) shortened the definition to 'the use of methods for the design, development and control of systems to identify, analyse and mitigate flood risks'. Much of this is represented in the ISO 31000:2009 standard for risk management (Purdy, 2010), which encompasses five phases (Figure 1-1): (i) establishing the context (i.e., 'What is to be achieved?'), (ii) identifying the risk (i.e., 'Which risks could happen, how, when, and why?'), (iii) analysing the risk (i.e., 'What can happen?'), (iv) evaluating the risk (i.e., 'Which risk is acceptable?'), and (v) mitigating the risk (i.e., 'How to reduce the risk?'). In terms of flood hazards, the mitigation phase encompasses risk reducing measures, which ranges from technical measures (e.g., improvement of forecasts, constructing or reinforcing levees and protective seawalls, etc.) to concepts for regional planning (e.g., prohibiting settlements in flood-prone areas) as well as measures for informing the public about being proactive and prepared (Martens *et al.*, 2009). The collection of identification, analysis and evaluation of risks is denoted as risk assessment.

Figure 1-1 depicts the risk management process as a circular process with step-like phases, though in practice there can be considerably interaction between the phases. Two activities work through all phases of the management process, namely monitoring and communication. Monitoring involves environmental scanning by risk owners, controlling assurance, collecting new information that becomes available, and learning lessons about risks and controls from the analysis of successes and failures. Continuous monitoring allows acting appropriately if new risks emerge or existing risks change in either the organization's objectives or the internal and external environment in which they are pursued (Purdy, 2010). The second continuous activity is the communication and consultation with internal and external stakeholders. Whereas internal stakeholders are experts in the risk management field, external stakeholders are decision-makers and the public. The importance of the stakeholders' objectives and views is being increasingly acknowledged in risk management (Petts, 2008; Milligan *et al.*, 2009).

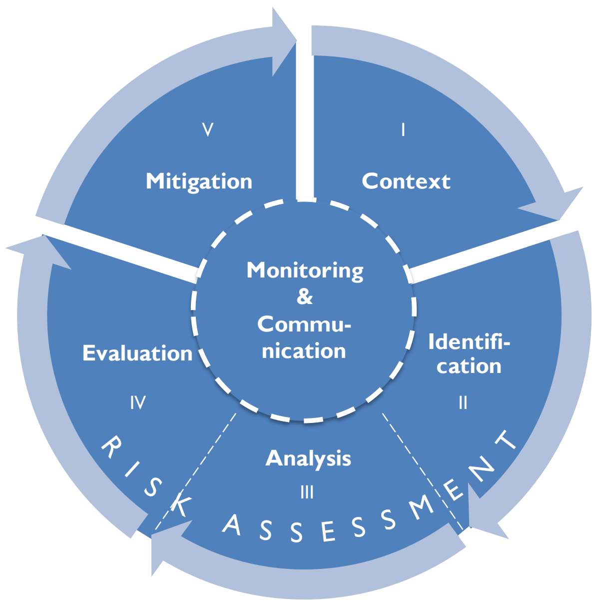

Figure 1-1 The circle of risk management

1.1.3 Objective versus subjective flood risk assessment

While quantitative aspects of flood hazards have been formerly studied predominantly by engineers and hydrologists, social aspects of floods have gathered increased attention in recent years, particularly among sociologists, geographers and environmental planners (Schanze, 2007). This evolution reflects the dual nature of risk, which has already been introduced earlier in this chapter. Two approaches are thus distinguished in flood risk assessment

(Smith and Petley, 2009). The first is the classic statistical approach, which is often denoted as the objective risk assessment or the risk-as-analysis approach (Slovic *et al.*, 2004). This approach defines flood risk as the product of hazard (i.e., the physical and statistical aspects of the actual flooding) and vulnerability (i.e., the exposure of people and assets to floods and the susceptibility of the elements at risk to suffer from flood damage) (Raaijmakers *et al.*, 2008; Meyer *et al.*, 2009). The second approach is based on people's subjective concerns, viewpoints and preferences (Sjöberg, 2000; Chauvin *et al.*, 2007). This perceived risk-approach pays attention to qualitative and intangible aspects of flood hazards, such as emotions, controllability, equity, uncertainty, etc. (Figueiredo *et al.*, 2009). Since feelings and emotions exhibit important factors in people's risk perception, Slovic *et al.* (2004) named this approach 'risk-as-feelings'.

Although the objective and subjective approaches are often presented as distinct risk assessment methods, they are not polar opposites (Renn, 1998b; Smith and Petley, 2009). For example, an individual's intuition may be unintentionally based on statistical knowledge of risk events. Conversely, even the most *objective* risk evaluation involves a range of *subjective* judgments, such as the ways in which different impacts are compared (e.g., assigning weights to various factors in a cost-benefit analysis). Smith and Petley (2009, p. 61) report that amongst academics controversy exists as to whether objective or subjective risk assessments should be given prominence in risk management decisions. Whereas objective risk assessment allows comparing risks appropriately, subjective risk assessment is better suited to comprise the complex nature of risk.

The understanding of the subjective risk assessment (or risk perception) is increasingly being recognized an important aspect of the decision making process to the point that some believe that the public perception of risk is already driving policy as much as technological and scientific risk assessments (Correia *et al.*, 1998; Tierney *et al.*, 2001). Renn (2004) elucidated this statement by arguing that risk perception research cannot replace science and policy though it can provide the impetus for the decision-making process. The European CRUE ERA-NET funding initiative for flood-oriented research admits that subjective risk assessment should not be neglected. This initiative states that the question of how people perceive, tolerate and accept flood risks is of vital interest in modern flood risk management, because it steers the development of effective and efficient flood mitigation strategies (www.crue-eranet.net). Several researchers (e.g., Enserink, 2004; Merz *et al.*, 2009) mention a growing concern to bring together the subjective and objective approaches in flood risk management.

A multidisciplinary and integrated approach is thus desirable, which not only includes experts and decision-makers, but also involves local stakeholders and the public (Brilly and Polic, 2005; Peacock *et al.*, 2005; Renn, 2005). This integration of both approaches may provide grounds for setting up effective risk communication strategies as well as for the creation and application of risk management policies and measures (Keller *et al.*, 2006; Figueiredo *et al.*, 2009).

The subsequent section briefly discusses the research in risk perception and its interaction with risk communication.

1.1.4 Research in risk perception and risk communication

Originated in the nuclear debate of the 1960s, risk perception research attempts to identify and clarify people's interests, views and needs regarding risks (Sowby, 1965; Starr, 1969). Through this research it became clear that advocates of nuclear energy focused on the low probabilities of a nuclear disaster, whereas opponents of this new technology mainly envisaged the catastrophic potential and the involuntariness of the risk. While these early studies were mainly based on *revealed* preferences (Barnett and Breakwell, 2001), subsequent research gradually evolved to psychological experiments and public surveys, in which people's perception could be assessed with *expressed* preferences (Palenchar and Heath, 2007). Three lines of research have emerged from this evolution.

A first line of research deals in essence with the quantification of risk perception. The psychometric studies of Fischhoff *et al.* (1978) and particularly Slovic (1987) pioneered in this regard by developing techniques to quantify and analyse people's preferences regarding various health and technological risks. Slovic's approach to risk perception is widely known as the Psychometric Paradigm. Despite criticism (e.g., Sjöberg, 2000), it remains a popular method in perception research to date. Closely linked to the psychometric approach is the heuristics method, which has its roots in the availability heuristics of Tversky and Kahnemann (1974), and which express simple and intuitive rules of thumb that people use to make decisions. Slovic *et al.* (2004) extended the heuristics approach to the study field of risk perception by defining the affect heuristic or the risk-as-feelings approach (Miceli *et al.*, 2008).

A second group of theories employs risk perception to examine, explain and predict people's behaviour regarding risks. This research line regards public perception of risk as an important predictor of how citizens will prepare for and respond to hazards (Peacock *et al.*, 2005). Prominent approaches in this context are the Protection Motivation Theory (Grothmann and Reusswig, 2006), the Protective Action Decision Model (Lindell and Perry, 2000), Contingent Valuation Methods (Zhai *et al.*, 2006) and qualitative research (Wagner, 2007).

A third line of research employs risk perception to improve risk communication strategies. This group of studies is based on the idea that the knowledge of someone's views and perceptions allows optimizing communication efforts about risk (Keller *et al.*, 2006; Bell and Tobin, 2007). In turn, effective risk communication largely determines how well people are prepared to face and deal with a risk (Basic, 2009). This interest in two-way communication is a recent development in risk communication, which has been emerged due to the failing of one-way communication and persuasive communication methods (Höppner *et al.*, 2010). Audience-based risk communication models comply with these recent developments. For instance, the Risk Information Seeking and Processing model (Griffin *et al.*, 1999) aims at identifying various factors that stimulate people to seek for risk information.

Since the 1980s, risk perception research is predominantly represented in health and technology sector (Renn, 2004). To date, numerous studies exist on the perception of epidemics, diseases, pollution, chemical waste and nuclear risks. However, due to the growing interest in climate change and the environment in general, perception research has also become rapidly present in the domain of natural hazards, such as earthquakes (e.g., Lindell and Perry, 2000; Lindell and Hwang, 2008), hurricanes (e.g., Peacock *et al.*, 2005; Arlikatti *et al.*, 2006; Horney *et al.*, 2010), volcanoes (e.g., Bird, 2009; Gavilanes-Ruiz *et al.*, 2009) and floods (e.g., Siegrist and Gutscher, 2006; Bell and Tobin, 2007; Zaalberg *et al.*, 2009; Terpstra, 2011). Despite the rapid growth of research on flood risk perception, several researchers recognize the study field is still in its infancy (Botzen *et al.*, 2009).

1.1.5 Coastal flood risks

During the last decade, several studies have reported increased flood risks in coastal areas worldwide (e.g., Dolan and Walker, 2006; Karim and Mimura, 2008; Lebbe *et al.*, 2008; Watkinson, 2009). Most researchers expect this trend to continue in the future. Two developments are generally put forward to substantiate this prediction.

First development is the global climate change, of which sea level rise is one of the most cited effects (Reynolds *et al.*, 2010). According to their fourth Assessment Report (Nicholls *et al.*, 2007), the Intergovernmental Panel on Climate Change (IPCC) predicts a global sea level rise up to 0.6 m or more by the end of the 21st century. Through the 20th century, global rise of sea level already contributed to increased coastal inundation, erosion and ecosystem losses, but with considerable local and regional variation due to other factors (Cooper and Jay, 2002; Cowell *et al.*, 2006). In addition to sea level rise, an increase in storm frequency and storm intensity is often predicted (McInnes *et al.*, 2003), albeit less accepted than sea level rise. Butler *et al.* (2007), for example, could not find a clear trend in the frequency of extreme storm levels in the North Sea area between 1955 and 2000. On the contrary, Lowe and Gregory (2005) reported an increase in the height of the 50-year extreme water level near London during the last 50 years. Regardless of their regional variability, the IPCC considers both factors as main climate drivers for coastal systems (Nicholls *et al.*, 2007).

Second development is the increasing urbanization degree in coastal areas. Buddemeier *et al.* (2002) pointed out that, although not all of the world's coastlines are inhabited, only few are beyond the influence of human pressures. The utilisation of the coast increased dramatically during the 20th century, a trend that is generally expected to continue through the 21st century (Nicholls *et al.*, 2007). The attractiveness of coastal areas has resulted in disproportionately rapid expansion of economic activity, settlements and urban centres (Burak *et al.*, 2004). This urbanization might be problematic if the coastal area is vulnerable to (sea) flooding. Smith and Petley (2009) have addressed such problematic urbanization as 'floodplain invasion', which is partly the result of the *levee effect*. This effect – originally introduced by Tobin (1995) – exists when flood defence structures (e.g., seawalls) are erroneously perceived as measures which assure full protection to the floodplain. Consequently, floodplains become urbanized, and eventually more property is placed at risk. An additional issue concerns coastal tourism, which is regarded as one of the fastest growing areas of the world's tourism industry (Miller, 1993; Hall, 2001). Because they are less independent and less familiar with the local environment and its hazards, tourists are regarded more vulnerable than locals in disaster situations (Burby and Wagner, 1996). Hence, coastal tourism may further increase the vulnerability of coastal areas with respect to storm surges and floods.

1.1.6 The Belgian coast in focus

The Belgian coastal plain is part of the maritime plain that extends along the North Sea from the cliffs of the Boulonnais (France) to Denmark. It is about 65 km long and 10 to 15 km wide, and comprises beach, dunes and polders (Belpaeme and Konings, 2004). The Belgian coast is characterized by an artificial linear coastline, which alternates dunes, harbours and urbanization. Overall, over 200,000 people reside in the coastal area. The relatively small coastal area is the setting for a number of widely divergent human activities, resulting in a high concentration as well as a complex spatial intertwining of functions, such as tourism, industry, fisheries and agriculture (Allaert, 1996; Broekx *et al.*, 2011). Tourism is considered as the most important economic activity in the coastal area. During summer, approximately 300,000 tourists reside daily in commercial accommodation (e.g., hotels, recreational parks, etc.) and second residences (private accommodation, with or without the intervention of a real estate office) (Gunst *et al.*, 2008).

The Belgian coast is protected against flooding from the sea by natural and artificial defence elements. Natural elements are dunes, sandbanks and beaches which form a protective belt of a few hundred meters to several kilometres wide and up to 30 meters high (Lebbe *et al.*, 2008). In addition, several places – particularly the harbours and the urbanized areas – are protected by artificial coastal defence techniques, such as groynes and seawalls. The latter were originally made of packed earth, later of stone and concrete. More than half the Belgian coastline is protected by one or several manmade reinforcements (Mertens *et al.*, 2010).

Previous storm surges have shown their adverse potential on the Belgian coast. Most salient is undoubtedly the storm surge of 1 February 1953, which resulted in a major flood in Oostende and the loss of several inhabitants. The quay-walls in the harbour of Oostende were simply too low, and consequently could not stop the rising water (N.N., 2003). Other coastal municipalities such as Knokke-Heist suffered large damage to their seawalls. In response to the 1953 storm surge, the Flemish Authorities heightened and reinforced the seawalls in the years ensuing the disaster (Charlier and Demeyer, 1995), yet insufficiently to serve protection against a more severe storm surge than the one from 1953.

Recent projects have put renewed attention to the safety of the Belgian coast against storm surges. First are the European Interreg projects COMRISK (2001-2005) and SafeCoast (2005-2008), in which Flanders served as research partner (led by the Agency for Maritime and Coastal Services). While both projects primarily focused on objective risk assessment, attention was also given to risk perception and public participation (COMRISK subproject 3 in Kaiser *et al.*, 2004) and risk communication (SafeCoast Action 2 in Knolle *et al.*, 2007). Both projects therefore conducted surveys in the countries surrounding the North Sea, including Belgium. Kaiser *et al.* (2004) found that Belgian respondents (N = 110; all inhabitants from Oostende) have the highest[1] dissatisfied percentage (56%) towards the coastal defence. In addition, the need for more information on coastal flood risks was highest in Belgium (78%). Only 14% of the respondents indicated to feel well-informed. This low percentage corresponded to the findings of Knolle *et al.* (2007), who commented on the limited number of communication means available to the Belgian public.

During the SafeCoast project, two Flemish projects were commenced, giving particular attention to the Belgian coast. First is the Master Plan for Coastal Safety (MPCS; formerly known as the Integrated Master Plan for Flanders Future Coastal Safety; 2007-2011), which encompasses the study of the safety level of the entire coastal area against storm surges, considering the effects of the climate change up till the year 2050 (Verwaest *et al.*, 2009). MPCS revealed that about one-third of the Belgian coast is insufficiently protected against a 1,000-year storm surge, which is set as the reference safety level. Future defence measures will mainly comprise beach nourishment and the construction of little storm walls on top of the current dikes (Mertens *et al.*, 2010). MPCS is thus in essence a technical approach to coastal flood risk. Second Flemish study is CLIMAR (Evaluation of climate change impacts and adaptation responses for marine activities; 2006-2011), which widens the scope of MPCS and examines all possible changes and necessary adaptations in

[1] Other study areas besides Oostende (Belgium) were: Ribe (Denmark), St. Peter-Ording (Germany), Sluis (the Netherlands), and Skegness (United Kingdom). Four hundred questionnaires were distributed in each municipality. Response rate was highest in Oostende (27.5%) and lowest in Skegness (11.3%) (Kaiser *et al.*, 2004).

the coastal area and its activities in order to cope with the climate change (Van den Eynde *et al.*, 2011). While CLIMAR incorporates a broader view on coastal flood risks, it is not intended to survey the public about its preferences and views on these risks.

1.2 Rationale and synopsis

The first part of this chapter has highlighted several important trends. First trend is the shift from a flood control to a risk-oriented approach to 'manage' flood hazards. Nonetheless, the dual nature of risk (objective versus subjective) has only recently been recognized an important aspect in flood risk management. Research in flood risk perception is emerging rapidly, demonstrating the need to consider the public's concerns, viewpoints and preferences. Inextricably bound up with the growing interest for risk perception is the increased attention for audience-based risk communication and public involvement in the decision-process. Second, coastal areas are becoming increasingly vulnerable to flooding, partly due to the effects of the climate change, partly due to the growing urbanization and economic development in these areas. Third, the Belgian coast is on the verge of realizing new defence measures to improve its protection against flooding.

These findings provide the main rationale of this dissertation, which is the examination of the objective and subjective flood risk assessment on the Belgian coast. Through mainly quantitative research via GIS and statistical methods, insights are acquired that could improve risk communication and consequently the public understanding and awareness of coastal flood risks.

The next two sections present the specific research questions of this dissertation and the general outline.

1.2.1 Research questions

This dissertation comprises five research questions which are triggered by three research objectives:

> *Objective A: To review the state of the art in research on objective and subjective flood risk assessment.*
>
> *Objective B: To analyse particular research gaps in objective and subjective flood risk assessment in coastal areas.*

> *Objective C: To suggest elements to improve flood risk communication in coastal areas.*

Whereas the first objective addresses general aspects and outcomes in flood risk research, the second and third objective focus on research gaps regarding coastal flood risks. Study area of these analyses is the Belgian coast.

Research objective A produces the following two research questions:[2]

> *RQ 1: What is the state of the art in flood risk management in Flanders and what are the future challenges?*
>
> *RQ 3: What is the state of the art in flood risk perception and flood risk communication research? Which methodologies are employed and what are the main findings and shortcomings in these research fields?*

The first research question concerns the state of the art of flood risk management in Flanders. It has been more than ten years that the Flemish Authorities have abandoned the flood control approach in favour of the risk-based approach. And still, a comprehensive review of the Flemish flood risk methodology is missing in literature. Furthermore, it would be interesting to map out the future challenges of flood risk management with regard to the European Floods Directive (2007/60/EC), which entered into force in 2007 and which obliges European countries to develop flood risk management plans by the end of 2015. Chapter 2 addresses these issues.

Research question 3 deals with the state of the art of research in flood risk perception and flood risk communication. Although the recent years have seen an increased interest for both study fields in flood risk management, the literature still lacks an overview of the findings in these domains. These objectives are discussed in Chapter 4.

Research objective B entails the following two research questions:

> *RQ 2: To what extent is coastal tourism an important factor in flood risk management of coastal areas?*
>
> *RQ 4: Which factors determine the public's flood risk perception in coastal areas? Does subjective risk assessment correspond to objective risk assessment and how is the geographic location linked to someone's perception?*

[2] The numbers of the research questions follow the order of the chapters in this dissertation (RQ 3 is handled in Chapter 4; RQ 2 is handled in Chapter 3).

Research question 2 addresses the general ignorance of tourists in flood risk management. Most studies use fixed population data in their flood risk analyses and rarely account for effects of population dynamics such as tourism (Lentz, 2006). Particularly in coastal areas, tourism can greatly influence the number of people that is exposed to a coastal flood hazard (Jonkman *et al.*, 2008). The seasonality of coastal tourism (especially in the middle latitudes) adds a temporal dimension to the problem. In Chapter 3, the application of a new data set is explored to deal with this spatiotemporal issue.

The fourth research question deals with the limited empirical evidence that exists for the theoretically assumed discrepancy between expert's versus lay people's (i.e., *objective* versus *subjective*) risk assessment (Wright *et al.*, 2002; Siegrist and Gutscher, 2006; Peacock *et al.*, 2005). In addition, the role of location has been underexposed in flood risk perception research (Heitz *et al.*, 2009). These and other issues are tackled in Chapter 5.

Research objective C triggers the fifth research question:

> *RQ 5: How can the knowledge of risk perception be informative to communication experts and what are the preferences and needs of the public towards flood risk communication?*

The fifth research question addresses the limited theoretical and empirical knowledge about the people's preferences, needs and behaviour towards flood risk communication. While several studies (e.g., Griffin *et al.*, 1999; Griffin *et al.*, 2008; ter Huurne and Gutteling, 2008) have put great effort to conceptualize predictors of information seeking behaviour and their relationships, their exist little empirical support of these models. Moreover, the complexity of these models hampers clear mediation analyses (Kahlor, 2010). In addition, several authors (e.g., Burn, 1999; Renn, 2005) have underlined the importance of knowing how people think about these risks so that communication can be refined to their needs. The fifth research question is addressed in Chapter 6.

1.2.2 Outline of the dissertation

This dissertation compiles five articles which have been published in or submitted to international peer-reviewed journals. Conform the research objectives, two out of five articles mainly review the contemporary research regarding (coastal) flood risks (Chapters 2 and 4). The other articles are analyses of various sets of survey data (Chapters 3, 5 and 6). Figure 1-2 depicts the general outline of the dissertation and shows how the chapters are linked to each other.

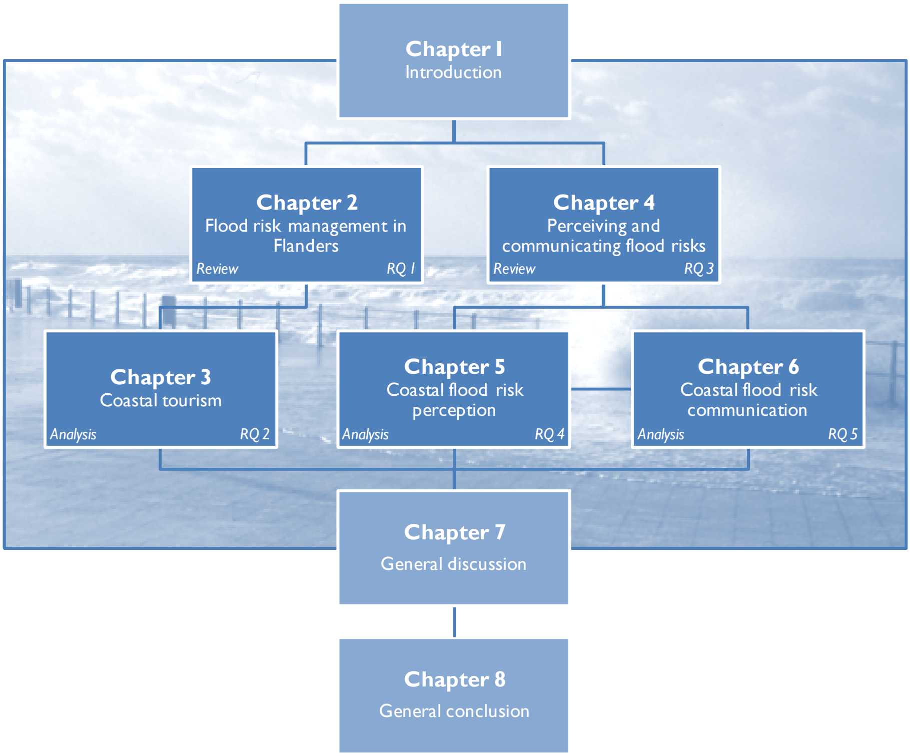

Figure 1-2 Outline of the dissertation

In Chapter 2, an overview is presented of the Flemish flood risk methodology, which has been developed at Flanders Hydraulics Research in close collaboration with Ghent University (Department of Geography). After illustrating the need for a risk-based approach, attention is given to reasoning and functioning of the approach, as well as to the implementation of the approach in GIS. Since the methodology is constantly under development, recent improvements are also discussed. Two case studies (one river and one coastal) further demonstrate the working of the methodology and the GIS tool. The chapter concludes with an overview of future challenges that are mainly caused by the requirements of the European Floods Directive (2007/60/EC), and a brief discussion on challenges regarding flood risk communication. The corresponding article to this chapter has been submitted for publication in *Water Resources Management* (Kellens *et al.*, 2011a).

Chapter 3, accepted for publication in *Natural Hazards* (Kellens *et al.*, 2011b), presents an analysis of the impact of coastal tourism on flood risk calculations. This chapter builds on the review of Chapter 2 and fills a gap regarding population dynamics. To this end, it examines to what extent the ignorance of (residential) coastal tourism may bias the calculations of flood casualties. Both the dynamic nature of coastal tourism and the behaviour of residential tourists in storm surge scenarios are considered. The entire Belgian coast is exerted as case study.

Chapter 4, submitted for publication in *Risk Analysis* (Kellens *et al.*, 2011c), provides a comprehensive review of the literature on flood risk perception and flood risk communication. The review comprises 57 empirically based peer-reviewed articles, gathered from the databases Web of Science and Scopus. This chapter demonstrates the growth of studies on flood risk perception, but moreover, it shows that there is hardly no methodological standardization at present, which makes it difficult to compare outcomes between studies. In addition, the review reveals that theoretical and empirical studies on flood risk communication are nearly nonexistent. A number of research gaps are subsequently tackled in Chapter 5 and 6.

Chapter 5, published in *Risk Analysis* (Kellens *et al.*, 2011d), presents an exploratory analysis of the flood risk perception on the Belgian coast. By means of a large-scale survey among the inhabitants and residential tourists of the Belgian coast, public risk judgments are compared to expert's risk assessments. Therefore, a high and a low risk area are selected for the study. In addition, various personal and residence characteristics are measured.

In the last analysis of this dissertation, Chapter 6, attention is paid to flood risk communication. Building on earlier information seeking models such as the Risk Information Seeking Process framework (Griffin *et al.*, 1999), this chapter focuses on the empirical relationships between information seeking behaviour and the constructs of risk perception, perceived hazard knowledge, response efficacy and information need. Particular attention is given to the mediating relationship of information need and to the effects of residing permanently in a flood-prone area or not. Data was collected in Oostende by means of a structured on-line questionnaire. In the form of an addendum, the chapter concludes with several qualitative findings on the public's information preferences and in this way addresses one of the future challenges that were discussed in Chapter 2. The corresponding article to Chapter 6 is under review for publication in *Risk Analysis* (Kellens *et al.*, 2011e).

Chapter 7 recapitulates the five research questions and presents a summary of and a general discussion on the outcomes of this dissertation. Avenues for further research are pointed out, as well as implications and challenges for policy makers. Finally, general conclusions are given in Chapter 8.

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2 FLOOD RISK MANAGEMENT IN FLANDERS: PAST DEVELOPMENTS AND FUTURE CHALLENGES

Modified from: *Kellens, W., Vanneuville, W., Verfaillie, E., Meire, E., Deckers, P., De Maeyer, P. 2011. Flood risk management in Flanders: Past developments and future challenges. (submitted for publication in Water Resources Management)*

Abstract

Flanders (northern part of Belgium) is a low-lying region vulnerable to flooding. Possible flood hazard sources are not only the many rivers which pass through the Flemish inland, but also the North Sea, which is sensitive to the predicted sea level rise and which can affect large parts of the Flemish coastal area. Due to the expected increase in flood risks in the 21st century, the Flemish Authorities have changed their flood management strategy from a flood control approach to a risk-based approach. Instead of focusing on protection against a certain water level, the objective now is to assure protection against the consequences of a flood, while considering its probability.

This chapter presents the state of the art of flood risk management in Flanders. In the first part, attention is given to the reasoning and functioning of the risk-based approach. Recent refinements to the approach are discussed, as well as the model's implementation in GIS. The functioning of the approach is subsequently demonstrated in two case studies. The second part of the chapter discusses future challenges for the flood risk management in Flanders. The driving force behind these challenges is the European Directive on the assessment and management of flood risks, which entered into force in 2007. The Flemish implementation of the directive is discussed and situated in the European landscape. Finally, attention is given to the communication of flood risks to the general public, since the 'availability' of flood risk management plans is among the requirements of the EU Floods Directive.

2.1 Introduction

Flanders is the low-lying northern part of Belgium, which geographically consists of a coastal basin plain that borders the North Sea in the north-west and a central plain that is characterized by a dense river network (cf. Figure 2-1). Most rivers are tributaries of the Scheldt, except for the Meuse (on the Belgian-Dutch border) and the Yser (in the west of Flanders). While the topography is relatively flat in the coastal basin and the northern part of Flanders, moderate valley slopes exist in the south of the region. Due to its high level of urbanization (average population density exceeds 460 inhabitants/km²) and its dense river network, Flanders is fairly sensitive to flood hazards. During heavy rainfall or long-lasting rainy weather, parts of Flanders can be flooded by overflow of river embankments (Deckers *et al.*, 2010; Broekx *et al.*, 2011).

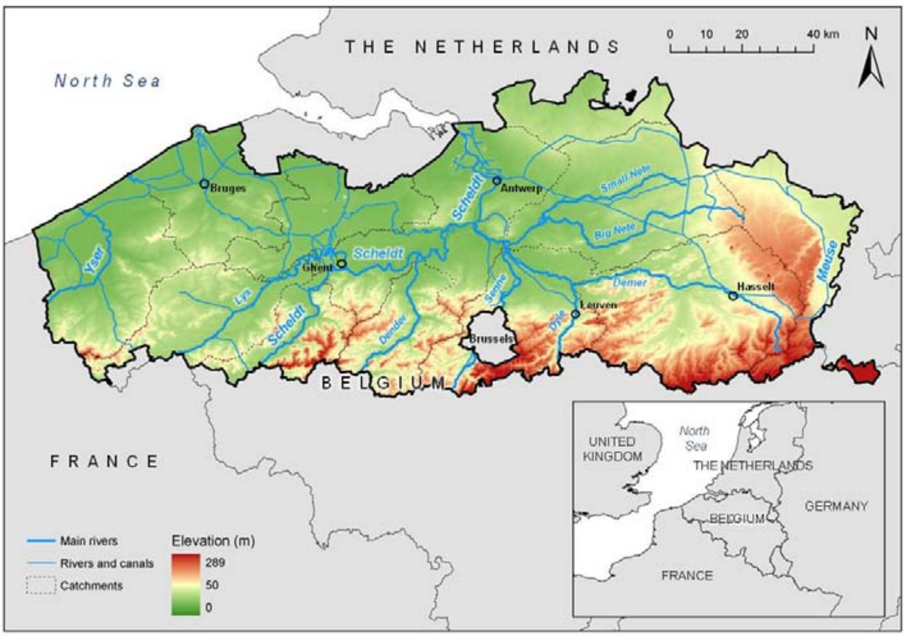

Figure 2-1 Location of the Flemish main rivers, smaller rivers, canals, catchments and topography

Other flood risks are related to storm winds above the North Sea, which can result in storm surges along the coastline and tidal waves rolling upstream on the Scheldt river, especially when the wind comes from a north-westerly or northerly direction. Examples are the storms of 1953 and 1976 which caused significant flood damage on the Belgian coast (specifically 1953) and along the Scheldt river. These floods gave rise to an increased public awareness of the flood risk and initiated the so-called Sigma plan (in which *S* stands for Scheldt) in the early 1980s. Originated as a flood control approach, the Sigma plan traced out a tidal storm surge barrier downstream Antwerp, a general heightening of the Scheldt river embankments and the construction of a number of controlled flood areas. Eventually, the storm surge barrier was never constructed since it could not be economically justified (Broekx *et al.*, 2011). However, due to sea level rise and economic developments, it is generally assumed that flood risks will increase significantly in the 21st century (Kundzewicz *et al.*, 2010; de Moel and Aerts, 2011). The Flemish Authorities responded to this prognosis by shifting from the flood control approach to a risk-based approach (Vanneuville *et al.*, 2003). As the name suggests, the risk-based approach puts a strong emphasis on flood risk, which is defined as flood damage that occurs or will be exceeded with a certain probability in a certain time period (e.g., one year) (Merz *et al.*, 2010). The movement from a flood control approach to a risk-based approach yielded a focal shift from protection against a certain water level to protection against the damage caused by the water. In practice, the risk-based approach led to an actualised Sigma plan in which flood safety is prioritized, though with nature restoration and the economic importance of the river (e.g., the harbour of Antwerp) as important parameters. In order to achieve this, controlled flooding zones, reduced tidal areas and wetlands are being installed to store abundant river water. In addition, dike enforcements and storm walls are foreseen to protect urbanised areas from flooding (Broekx *et al.*, 2011).

Initially, the implementation of a risk-based approach implied two objectives in Flanders. The first objective yielded the development of a uniform method which allowed comparing risks geographically or over time (e.g., impact of infrastructure works). Alternatives are *ex ante* compared to evaluate cost-efficiency and prioritize them. The second objective consisted of defining the necessary data and software for executing the risk calculations. A third objective was added in 2007, when the European Union enforced the Floods Directive (2007/60/EC). The goal of this directive is to establish a framework for the assessment and management of flood risk in Europe, emphasizing both the frequency and magnitude of a flood as well as its consequences (de Moel *et al.*, 2009).

This chapter provides an overview of the state of the art of flood risk management in Flanders. The first part (*past developments*) describes the risk-based approach in detail, together with some recent additions to the methodology and the model's implementation in GIS. The chapter subsequently exemplifies several aspects of the risk-based approach with two case studies (river and coast). The second part (*future challenges*) discusses the implementation of the European Floods Directive in Flanders' flood risk management and briefly comments on the Flemish situation in the European landscape. The chapter ends with a discussion on flood risk communication.

2.2 Past developments

2.2.1 A risk-based approach

The Flemish risk-based approach finds its origins in the early 2000s as a cooperation between Flanders Hydraulics Research (Flemish Authorities) and the Department of Geography (Ghent University). It adopts the general definition of flood risk as the combination of the probability of a flood event with its (negative) consequences or losses (Smith and Petley, 2009). While a substantial body of international literature provides evidence of extensive expertise in the field of damage estimation, experts and academics disagree about the methods and models to be applied. Jonkman *et al.* (2008) identify three elements of dispute, which are discussed hereafter: (i) damage definition, (ii) damage appraisal and (iii) scale of analysis.

Previous literature has defined flood damage in numerous ways. Common distinctions are between direct and indirect damage, and between tangible and intangible damage (priced versus unpriced). However, interpretations and delineations of what is considered a direct and indirect impact differ (Jonkman *et al.*, 2008). In Flanders, the distinction between direct and indirect damage is used to indicate whether flood impacts are first-order (they occur at the time of flooding) or second-order (they occur after the flood). As such, direct/indirect comprises a time shift in damage. Geographical distinction between damage inside and outside the flooded area is designated by the terms internal and external damage. According to these definitions, it is impossible to have direct damage outside the flood area. Initial focus of the Flemish risk-based approach lied on internal tangible damage assessment, both direct and indirect (e.g., production losses, clean-up costs). Soon, the inclusion of casualty calculations (intangible damage) was added to the model (Vanneuville *et al.*, 2003). Although models have been suggested (see Merz *et al.*, 2010) to valuate indirect, external damages (such as production losses in companies outside the flooded area), they have been found difficult to apply, due to reasons of limited data availability and a complex economic network (Rodrigues *et al.*, 2002; Deckers *et al.*, 2010). Since data uniformity is one of the key objectives of the Flemish risk approach, indirect external costs are currently not considered. Up till now, intangible costs such as health effects and losses to cultural heritage are also not considered in the approach. As these impacts are requested in the EU Floods Directive, it will be a challenge to incorporate them in the near future (cf. Section 2.3).

Jonkman *et al.* (2008) further indicate that various perspectives exist regarding damage appraisal. While some authors (e.g., Merz *et al.*, 2010) prefer to use depreciated values, others (e.g., Vrisou van Eck *et al.*, 1999; Vanneuville *et al.*, 2003) have chosen to use replacement values. Choosing between depreciated or replacement values depends on the definition of risk: macro-economic versus financial risk. Merz *et al.* (2010) advocate the use of depreciated values in risk management, which are suitable to calculate macro-economic risks. Replacement values on the contrary, are more appropriate to calculate financial risks. An example: a bakery, located in a flood area, might result in financial risks for the baker. However, if people are able to buy their bread elsewhere, there is no (macro-)economic risk involved in this. The advantage of calculating macro-economic risks is its accuracy, on condition that sufficient information is available, which is at the same time a significant disadvantage. Although replacement values may imply simplification and overestimation of the actual risk, they are generally easier to access and process.

Finally, the chosen scale of analysis may lead to variations in the risk methodology. Since Flanders is a relatively small region, all calculations can be performed at micro- to meso-level, being 5 x 5 m grids. This is a relatively high resolution compared to the 100 x 100 m grids that are usually applied in flood risk management (Jonkman *et al.*, 2008).

Figure 2-2 depicts the flow chart of the Flemish risk-based approach, which consists of three calculation phases: (i) flood hazard calculations (probability and physical extent), (ii) vulnerability and damage calculations and (iii) flood risk calculations. The following sections describe each of these phases in more detail. Because of the scope of this chapter, particular attention is given to the second and the third phase.

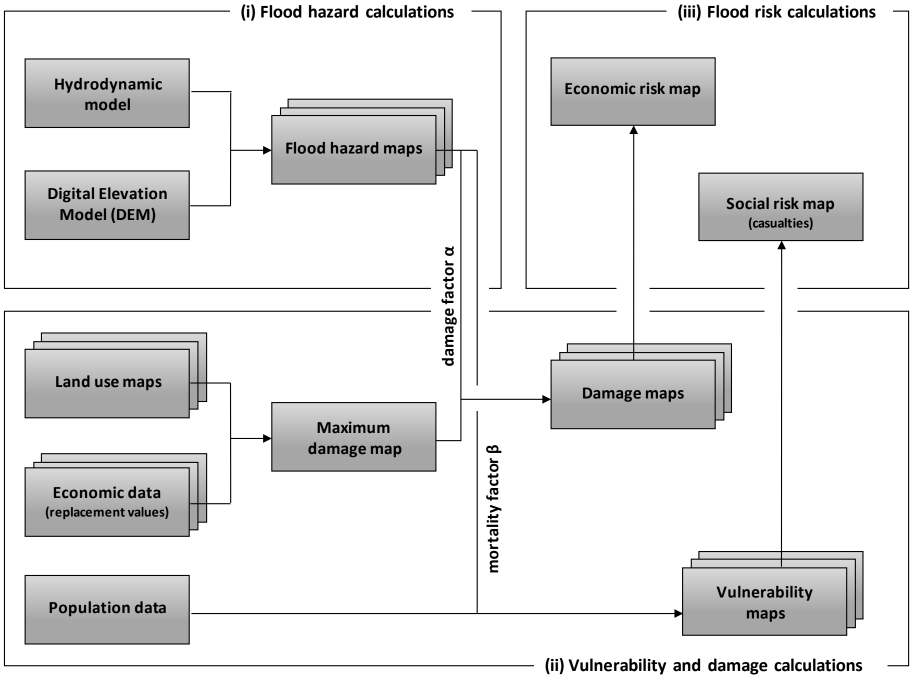

Figure 2-2 Flow chart of the Flemish risk-based approach

Flood hazard calculations

The first phase in the risk-based approach involves the computation of a set of flood hazard maps from various hydrodynamic models and a high-resolution digital elevation model (known as *DHM Vlaanderen*, with an average vertical accuracy of 7 cm on hard surfaces and short grass). The generated hazard maps each represent the physical extent of a flood with its particular return period (probability). Higher water levels correspond to larger return periods of occurrence. The flood maps not only show maximum water level in each grid cell, but indirectly indicate the spatial extent of a specific inundation. Other parameters, such as flow velocity and the rate at which the water rises are also mapped.

Vulnerability and damage calculations

The second phase forms the heart of the risk-based approach. Using various geographic and socio-economic data, damage (i.e., economic damage) and vulnerability (i.e., casualties) maps are computed.

Table 2-1 Overview of categories (land use and objects) that are considered in damage calculations (damage values are in Euros)

Categories	**Meas. Unit**	**Max. Direct Damage**	**Categories**	**Meas. Unit**	**Max. Direct Damage**
Roads			*Recreational Area*	m²	0.03
Highways	m	1,650	*Cropland*	m²	0.3 - 2.1
Major roads	m	850	*Pasture*	m²	0.08
Regional roads	m	750	*Special buildings and constructions*		
Connecting roads	m	700			
Access Roads	m	300	Hospital	m²	1,400
Railways			City Hall, School	m²	1,400
Singular Railways	m	625	Fire, Police Station, Prison	m²	1,560
Multiple Railways	m	7,500			
Urban area			Church, Abbey, Monastery	m²	1,400
Buildings (*)	m²	500 - 2,400			
Furniture	m²	30% of (*)	Museum	m²	1,560
Open Space	m²	1	Shopping centre	m²	5,300
Industrial area			Castle	m²	19,500
Buildings	m²	100 - 680	Gas Station	object	900,000
Open space	m²	100	Wind Mill	object	687,500
Airport	m²	100	Wind Turbine	object	712,000
			Cars	object	4,500

Since there is no information on the damage behaviour of each object and/or because such a detailed assessment would require a huge effort, it is not possible to assess the maximum damage for each single object (Merz *et al.*, 2010). Therefore, elements at risk are pooled into classes, and the damage assessment is performed equally for each of these classes. In the Flemish risk methodology, groups of elements are mainly based on land use classification. Using different data sets with land use information, a number of land use classes are defined, for example urban area, industrial area, infrastructure, crop land, pastures, etc. (cf. Table 2-1). These classes are further divided into various sub-classes, for example 16 different classes are defined for industrial buildings (e.g., chemical industry, food industry, metallurgical industry, etc.). For residential housing, distinction is made between the value of the building (fixed asset) and the value of the contents (e.g., furniture). Numerous line and point elements (such as roads, railroads, hospitals, telecommunication towers, etc.) are added afterwards. Replacement values are subsequently assigned to these groups of elements.

Next, damage functions are employed to determine the expected damage for each return period. Damage functions relate expected damage for the respective group of elements at risk to characteristics of the inundation (Pistrika and Jonkman, 2010). In general, distinction is made between empirical damage functions (based on historical data) and expert damage functions (based on expert judgment). While the former is a popular method in the UK and the Netherlands, the latter method is preferred in Germany and France (de Moel and Aerts, 2011). Currently, Flanders employs expert damage functions, adopted from Vrisou van Eck *et al.* (1999), Van der Sande (2001) and Penning-Rowsell *et al.* (2005). In the future, however, it is planned to move towards empirical damage functions using damage information from recent flood events. Figure 2-3 depicts several damage functions which are currently in use in the Flemish risk approach. The graphs represent the expected damage (as damage factor α in percentages) for three land use classes (roads, industry and residential housing) and goods (furniture) as a function of the water depth. Notice the 'flat' stroke between 1 and 2 m for furniture. This signifies that between a water depth of 1 and 2 m, no extra damage is expected with increasing water depth, since most furniture is lost anyhow. However, once the water depth exceeds 2 m, furniture of the first floor can be damaged as well, so the damage function increases again. All damage factors are equal to 1 if the water depth amounts to 5 m or more.

Finally, the maximum damage map is combined with the set of flood maps which results in a set of damage maps for each return period. The expected damage D_{exp} can be mathematically described as follows:

$$D_{exp} = \sum_{entities} \alpha * D_{max} * N \quad (1)$$

Where: D_{max}: maximal (potential) damage in a certain land occupation

α: coefficient expressing the relation between water depth and damage (cf. Figure 2-3)

N: number of entities

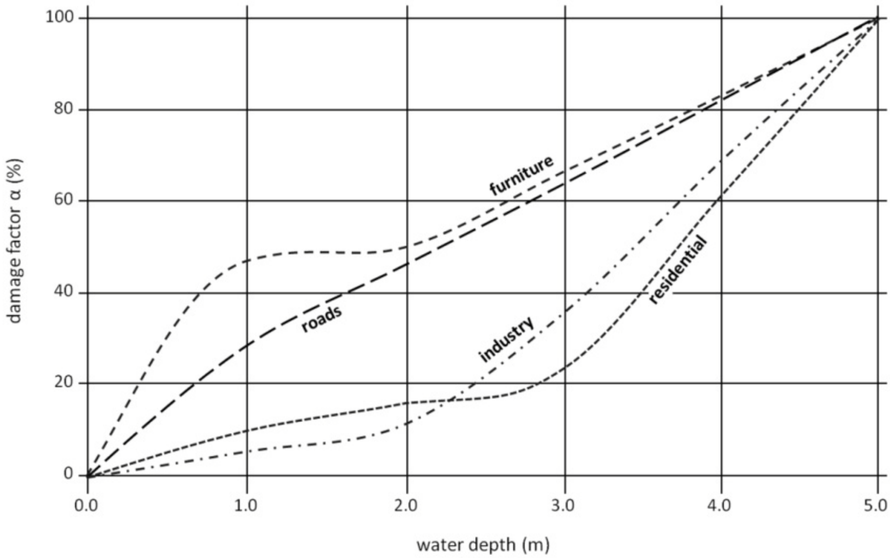

Figure 2-3 Damage functions: expected damage for different land use classes (roads, industry and residential housing) and goods (furniture) as a function of water depth (Deckers *et al.*, 2010)

While the overflow of dikes (i.e., river embankments or seawalls) is the main cause of flooding in Flanders (Broekx *et al.*, 2011), other flood causes are also examined, such as geotechnical failure or dike breaching. Due to the high flow velocity in the vicinity of a breach, damage to built-up areas may be much larger than in an overflow scenario. In general, it is assumed that flow velocity generates an additional damage on top of the present damage calculations based purely on water depth. Based on findings of Vrisou van Eck *et al.* (1999), new damage functions were developed for levels of water depth in combination with flow velocity (Verwaest, 2007). These functions define a flow velocity of 3 m/s and a water depth of 0.5 m as thresholds for buildings to collapse. Thus if both thresholds are exceeded, a maximum damage is applied. On the Belgian coast, dune breaching is also considered.

The second phase additionally involves the calculation of vulnerability maps which represent the number of expected casualties among the population exposed to the flood hazard. People are especially vulnerable to rapidly rising and/or flowing water and debris flows (Jonkman and Penning-Rowsell, 2008). In the Flemish risk-based approach, no monetary value is attributed to human life. Casualties are instead calculated in persons/m². Three steps are generally defined in these calculations (Jonkman, 2007). The first step involves the assessment of physical effects associated with the flood, including the dispersion of the effects and the extent of the exposed area. Relevant flood characteristics for casualty calculations are water depth, the rate at which the flood water rises, and the flow velocity. In the second step, the number of people exposed to the hazard is determined. Jonkman *et al.* (2008) has argued that in large-scale applications with high population numbers, the number of people exposed can safely be approximated by the registered population in the area (the number of inhabitants). When a flood occurs, however, the actual number of people exposed might differ significantly from the registered population. The number might be underestimated when large numbers of tourists visit the area regularly, for example in coastal areas. The number of people exposed might be overestimated as well, for example due to timely evacuation of inhabitants. Although steps have been taken to consider tourist numbers and evacuation effects, it remains challenging to find and employ useful data sets in this regard (Kellens *et al.*, 2011a). Therefore, the Flemish risk methodology largely relies on the registered population to calculate the number of people that could be exposed to a flood hazard. In the third step, the casualty number amongst the exposed population is estimated using so-called mortality functions. Analogous to the damage functions, mortality functions depict the expected percentage of casualties given a particular flood characteristic, such as water depth, rise velocity, and flow velocity (discharge). For water depth and rise velocity, values were taken from the empirical research work of Vrisou van Eck *et al.* (1999). According to their findings, the number of casualties grows exponentially with water depth d:

$$f_d = e^{(1.16d - 7.3)} \qquad \text{with} \qquad f_d \leq 1 \qquad (2)$$

Where: f_d: mortality factor in function of water depth

d: water depth in meter

e: mathematical constant = 2.718

The mortality factor f_d reaches 1 with a water depth of 6.3 m or more. The expected number of casualties further increases linearly with rise velocity r:

$$f_r = 0.37r - 0.11 \qquad \text{with} \qquad 0.3 \leq r \leq 3.0 \qquad (3)$$

Where: f_r: mortality factor in function of rise velocity

r: rate at which water rises (m/h)

The condition in Equation 3 signifies that if $r < 0.3$ m/h, no casualties are expected as a result of rise velocity. However, if $r > 3.0$ m/h, 100%

mortality is expected among the people exposed. With regard to flow velocity, useful parameters were found in empirical research on building resistance. Vrisou Van Eck *et al.* (1999) showed that walls will collapse if the product of flow velocity and water depth exceeds 1.5 $m^3/m/s$. These conditions correspond to a mortality of 100%.

Risk calculations

In the third and final phase, the damage and vulnerability maps are combined into economic flood risk maps, which express the mean annual damage per surface per year, and into social flood risk maps, which express the mean annual expected victims. As mentioned before, risk combines both the probability of a flood event (return period) and its consequences (expected losses). Computing the risk for any flood event implies a summation of all the expected damages for the set of return periods while considering probabilities and earlier damage calculations (in order to avoid damage to be counted multiple times). The risk R is mathematically defined as follows:

$$R = \sum_{i=1}^{n} \frac{1}{i} (D_i - D_{i-1}) \tag{4}$$

Where: D_i: damage related to a flood event with a return period of i time (e.g., year)

n: the highest return period which is considered

Equation 4 should be read as: the risk is equal to the damage of a flood event with a 1-year return period, added by half the damage of a flood event with a 2-year return period and subtracted by the damage of the event with a 1-year return period, added by a third of the damage of a flood event with a 3-year return period, etc.

2.2.2 Recent refinements

The Flemish risk-based approach has been recently extended with a number of refinements. Among the most important are (i) the inclusion of time dependency for agriculture, and (ii) a revision of the land use maps.

In earlier versions of the risk-based approach, the estimated damage of the agricultural land use categories (pastures and croplands) was entirely based on water depth. However, as De Nocker *et al.* (2007) indicate, the amount of agricultural damage is more dependent on the moment of a flood (i.e., a flood in the winter will cause less damage than a flood in the summer just before harvesting) than on the water depth (i.e., for most crops, it makes no difference if the water depth is 20 cm or 2 m). Therefore, new damage functions for croplands and pastures were developed. Based on the life cycle (seeding, growing, harvesting) and the relative occurrence of the most common Flemish crops (De Nocker *et al.*, 2007), the degree of occupation of the croplands was calculated for the different months and for different regions in Flanders. This degree of occupation is implemented in the risk methodology so the estimated flood damage to agriculture now differs from season to season.

A second refinement concerns the use of more detailed land use information. In the original methodology, land use classification was based on CORINE Land Cover maps (100 x 100 m^2) and the Small Scale Land Use Map of Flanders (20 x 20 m^2); both are based on classifications of satellite images and particularly useful for small-scale applications. Information about the location of objects, such as special buildings and constructions, was subsequently added to the land use data as an XY-coordinate. This approach appeared useful for damage and risk calculations on river catchment level (de Moel and Aerts, 2011). In recent years, however, the need to perform risk calculations at higher detail levels (e.g., along small unnavigable brooks) has increased. New data sets meet this need. At the catchment level, a vector-based data set (Biological Valuation Map of Flanders) is now used to define land use classes. In addition, high-detailed cadastral information is applied to represent the exact location of the residential and industrial buildings. Moreover, special buildings like hospitals, schools, etc. (cf. Table 2-1) are no longer represented as points with XY-coordinates but are now represented by their surface area based on large-scale topographical data.

2.2.3 GIS implementation

As Jonkman *et al.* (2008) recognize, geographical information is the key binding element in flood risk modelling. In a GIS environment, various data sources related to topography, land use, economic activities, population, etc. can be overlaid and analysed. A GIS is thus without doubt the best aid to implement the risk-based approach so that risk calculations can be operationalized.

The Flemish risk-based methodology was first implemented by the model builder of the general raster-GIS IDRISI. However, this implementation posed some disadvantages, such as (i) user-unfriendly interface, (ii) time-consuming model start-up, (iii) non-effective data management and (iv) long calculation times (as a result of the disadvantages (i) to (iii)). It followed that the development of a user-friendly, tailor-made, effective tool for flood risk assessment was felt necessary (Deckers *et al.*, 2010). In cooperation with Ghent University, Flanders Hydraulics Research developed a new tool to answer these needs, LATIS. Using the computing capacity and built-in standard modules of IDRISI, LATIS allows calculating damage and risk maps in Flanders in an easy (the user only has to take care of input flood hazard maps), uniform (same method and data for the whole territory of Flanders) and reproducible way (data management system records the set of input data).

LATIS is currently being employed by researchers at Flanders Hydraulics Research and the Flemish Environment Agency (VMM) as a decision support tool for policy makers and flood risk managers. LATIS is also applied in the two case studies which are described hereafter.

2.2.4 Case studies

This section presents two case studies. A first case study involves scenario calculations in the catchment of the Yser river. A second case study focuses on damage and casualty calculations along the Belgian coast. Whereas the river study demonstrates the latest refinements to the risk-based approach (being the inclusion of time dependency for agriculture and the revised land use maps), the coastal study examines the economic and social vulnerability in the coastal area due to overflow of seawalls and/or dike breaching.

Flood risks in the Yser catchment

The Yser is the only Belgian river that discharges into the North Sea on Belgian territory. The river finds its origin in the north of France (close to Kassel), enters Belgium near Houtkerque and flows into the North Sea in the town Nieuwpoort (cf. Figure 2-4). The Yser measures 78 km and carries down water from a 1100 km² large basin area. About two thirds of its length and basin area are located in the Belgian province West Flanders. On Belgian territory, the Yser is a typical low-land river with a very small drop: only 4 m over 45 km or 0.08 m/km. About 35% of the river basin comprises polders (croplands and pasture). The municipalities of Diksmuide (approx. 16,000 inhabitants) and Nieuwpoort (approx. 11,000 inhabitants) make up the most important urban areas along the Yser.

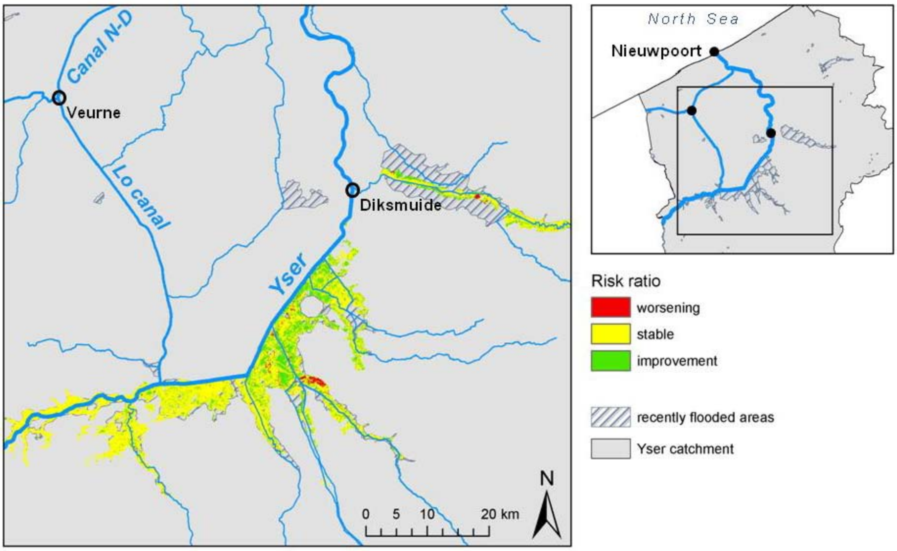

Figure 2-4 Recently flooded areas and risk ratio in the Yser catchment. The risk ratio depicts the change in flood risk between the reference scenario and the building of pumps on the Yser in Nieuwpoort

A weir in Nieuwpoort closes the Yser from the North Sea tide fluctuations, which makes river discharge only possible at low tide (Heylen, 1997). In the case of high water levels on the Yser, water can be discharged through the Lo canal and the canal Nieuwpoort-Dunkerque (indicated by 'Canal N-D' in Figure 2-4). In the past, the Yser has frequently caused extensive floods in the western part of Flanders. In the case of heavy and prolonged rainfall, the Yser's water level can increase rapidly, especially when the weir in Nieuwpoort is closed due to high sea tide. Discharge through the Lo canal may then not be sufficient (Heylen, 1997). Recent severe floods have occurred in the winter of 2002/2003 (D'Haeseleer and Vanneuville, 2006). Figure 2-4 depicts the recently flooded areas as dashed polygons.

In 2006, Flanders Hydraulics Research was commissioned by the Department of Waterways and Sea Canal to examine the effects of the installation of pumps along the Yser (in Nieuwpoort and Veurne) and of adjustments along the Lo canal. Apart from studying the hydrological and hydraulic impacts of each of these scenarios on the Yser discharge, attention was also given to the effects on flood damage and risk calculations (D'Haeseleer and Vanneuville, 2006). Four scenarios were considered (cf. Table 2-2):

- reference scenario (denoted as ‘reference’): this is the current situation;
- raising of the maximum water level in the Lo canal from 3.50 m TAW[3] to 3.70 m TAW (denoted as ‘Lo canal’);
- construction of emergency pumps in Veurne (denoted as ‘Pumps_V’), which makes permanent water discharge in the Lo canal possible in the case of high water levels on the Yser;
- construction of pumps on the Yser in Nieuwpoort (denoted as ‘Pumps_N’), so that water discharge from the Yser can be assured, even if the weir is closed during high sea tide.

Flood risks were calculated from a set of damage maps with different return periods (1, 2, 5, 10, 25, 50 and 100 years). Table 2-2 shows the estimated flood risks for each of the scenarios per summer half year (1 April – 1 October) and per winter half year (1 October – 1 April) for different land use classes. The ‘ratio’-value depicts the risk change as compared to the reference scenario. Apparently, only the scenario with the construction of pumps in Nieuwpoort results in a relatively significant risk reduction of 8.4 % in summer and 6.2 % in winter. Figure 2-4 shows the geographical location of this risk reduction. Green pixels represent an improvement or reduction of the flood risk, red pixels represent a worsening of the risk. Apart from depicting the risk ratio, the map also shows that most of the flood risk is expected to occur upstream from Diksmuide along a number of tributaries of the Yser. As Table 2-2 indicates, these areas are mainly occupied by croplands and pastures. Both land use classes represent about 83% of the flood risk in the summer half year. However, their contribution to the total risk drops to about 21 % in the winter half year. Since the summer months are crucial for crops and their life cycle (cf. Section 2.2), the losses caused by flooded cropland are much larger in summer than in winter (factor 6). For pasture, the differences are even bigger. This can be explained by the cutting regime of hay, which amounts to about five cutting turns between April and October,

[3] TAW is a Dutch abbreviation for “Tweede Algemene Waterpassing”. An altitude of 0 m TAW corresponds to the average low spring tide level at Oostende.

but none in the winter months. Consequently, flooded pasture does not entail economic damage during this season (De Nocker *et al.*, 2007).

Noteworthy is that the same set of flood hazard maps were used in both summer and winter scenario. An equal chance of flooding is thus assumed between summer and winter flooding. In Belgium, average precipitation numbers are effectively similar between the summer and winter half year (411.3 mm versus 441.1 mm respectively), though analysis of time series over 100 years showed that there is a trend towards more extreme rain showers in the winter (Ntegeka and Willems, 2008). In addition, the winter implies a higher probability of storm at sea which subsequently limits the discharge possibilities of the Yser.

Table 2-2 Estimated flood risk (in thousands of Euros per half year) in summer half year and in winter half year

	Reference		**Lo canal**		**Pumps_V**		**Pumps_N**	
Land use	S	W	S	W	S	W	S	W
Roads and railways	45.0	45.0	43.5	43.5	44.5	44.5	40.0	40.0
Urban area (buildings)	3.2	3.2	3.1	3.1	3.1	3.1	3.0	3.0
Urban area (open space)	11.5	11.5	11.4	11.4	11.4	11.4	10.8	10.8
Industrial area (buildings)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Industrial area (open space)	17.5	17.5	17.0	17.0	17.5	17.5	16.0	16.0
Cropland	257.5	42.5	250.0	41.0	256.0	42.5	233.0	38.5
Pasture	510.0	0.0	503.5	0.0	507.5	0.0	466.0	0.0
Wind turbine	74.0	74.0	73.0	73.0	74.0	74.0	73.0	73.0
Total	918.6	193.6	901.4	188.9	914.0	193.0	841.8	181.3
Ratio (%)	100	100	98.1	97.9	99.5	99.7	91.6	93.8

S = Summer; W = Winter

Table 2-3 shows the flood risk estimations for the Yser catchment based on two different land use maps, namely the 'old' land use map based on small-scale information (CORINE Land Cover and the Small Scale Land Use Map of Flanders), and the 'new' land use map based on high-detailed vector information (Biological Valuation Map of Flanders and cadastral data; cf. Section 2.2). Average annual damage values were used for agriculture.

Just as in the previous risk calculations (cf. Table 2-2), the installation of pumps in Nieuwpoort is denoted as the best scenario. The risk improvement amounts to about 8% with the 'new' land use map and over 10% with the 'old' land use map. The largest differences between both land use maps are observed for the roads and railways. The reduction of 75 % of the flood risk with the new land use maps can be attributed to a different road classification. Whereas 30 types of roads were distinguished in the old land use data (i.e., TOP50v), the number of types was limited to five in the new land use data (i.e., NAVStreet). Although the reclassification of road types was based on a 'best fit' for Flanders, disparities are possible in areas with an overrepresentation of a certain road type. Next, an increase in flood risk for cropland is observed in the new land use data. This seems complementary with the decrease in flood risk for open space. The high detail-level of the cadastral information allows a better differentiation between open space area and cropland and pasture. The remaining classes do not differ significantly between both data sets. All together, there is a flood risk reduction of about 20 % with the new land use data, compared to the old data.

Table 2-3 Estimated flood risk (in thousands of Euros per year) according to the old and the new land use data set

	Reference		**Lo canal**		**Pumps_V**		**Pumps_N**	
Land use	Old	New	Old	New	Old	New	Old	New
Roads and railways	338	90	332	87	337	89	319	80
Urban area (buildings)	8.5	6.3	8.4	6.1	8.5	6.2	7.9	5.9
Urban area (open space)	32.3	22.9	32.1	22.7	32.1	22.8	26.9	21.6
Industrial area (buildings)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Industrial area (open space)	75.2	34.5	74.6	34.2	74.7	34.5	23.4	31.7
Cropland	264	297	259	288	263	295	246	269
Pasture	502	510	495	504	500	508	458	466
Wind turbine	148	148	146	146	148	148	146	146
Total	1368	1108	1348	1088	1362	1103	1227	1020
Ratio (%)	100	100	98.5	98.2	99.6	99.5	89.7	92.1

Two conclusions can be drawn from this case study. First, the scenario with the installation of pumps in Nieuwpoort has shown to be the best scenario in terms of flood risk reduction. Obviously, other aspects – e.g., environmental, social and technical constraints – will have to be considered in the decision-making process. To this end, techniques such as a multi-criteria analysis can be employed (Costa *et al.*, 2004). Second, the case study has demonstrated the importance of employing risk values in a relative way. Methodological refinements such as the inclusion of time dependency for agriculture and the revision of land use maps can have major effects on absolute flood risk values, although the case study showed minor changes at the relative level.

Impact of storm surges on the Belgian coast

The Belgian coast is located on the Southern Bight of the North Sea and is characterized by an artificial linear coastline, which alternates dunes, harbours and urbanization. The relatively small coastal area is the setting for a number of widely divergent human activities, resulting in a high concentration as well as a complex spatial intertwining of functions, such as tourism, industry, fisheries and agriculture (Belpaeme and Konings, 2004). Overall, over 200,000 people reside in the coastal area. During summer holidays, this number is doubled by residential tourists (Gunst *et al.*, 2008).

The Belgian coast is protected against flooding from the sea by natural and artificial defence elements. Natural elements are dunes, sandbanks and beaches which form a protective belt of a few hundred meters to several kilometres wide and up to 30 meters high. In addition, several places – particularly the harbours and the urbanized areas – are protected by artificial coastal defence techniques, such as groynes and seawalls. Hence, more than half the Belgian coastline is protected by one or several manmade reinforcements. Without these artificial reinforcements, major parts of coastal area and the low-lying polders would easily inundate, even by a yearly storm.

Recent studies have been commenced to improve the coastal safety, thereby considering the effects of the climate change and the subsequent sea level rise for the North Sea region up to the year 2050. Together, these studies form the Master Plan for Coastal Safety (MPCS; Agency for Maritime and Coastal Services). Analogous to river floods, risk calculations are employed to measure the possible effects of a severe storm surge on the coastal area (Mertens *et al.*, 2010). Whereas the return period of the Flemish rivers are in the order of 1 to 100 years, it is relevant to take much smaller probabilities into account with regard to coastal flood risks. However, relatively little reliable scientific knowledge exists about such super storm surges. Flood risk calculations in the frame of the MPCS are therefore performed with an alternative, probabilistic risk formula that is based on the weighted average of a number of storm events (Verwaest *et al.*, 2008).

As described in Section 2.1.2, a number of context-specific aspects are considered in the computation of coastal flood risk calculations (both damage and casualties), such as overflow, (dike) breaching and flow velocities. Table 2-4 gives an overview of the output of these calculations for the three major coastal areas (cf. Figure 2-5 or Figure 2-6 for their location). With regard to the specific location of the flood 'source', four types are considered:

- type A: on the seawall as a result of water overflow and/or breaches;
- type B: in the flooded interior as a result of water overflow and/or breaches in the seawall near coastal municipalities and villages;
- type C: in the flooded interior as a result of water overflow and/or breaches in harbours (only relevant for the municipalities of Nieuwpoort, Blankenberge and Zeebrugge);
- type D: in the flooded interior as a result of water overflow and/or breaches in the city of Oostende (on the seawall or in the harbour).[4]

Table 2-4 Damage and casualty risks for the Belgian coast

	Damage risks (in 100,000 Euros per year)					Casualty risks (in numbers per year)				
Coast	A	B	C	D	Tot.	A	B	C	D	Tot.
West	0.03	0.00	12.76	-	12.79	0.03	0.00	0.17	-	0.20
	0.20	*0.03*	*99.77*	-	*100*	*16.74*	*0.06*	*83.19*	-	*100*
Middle	0.28	1.79	0.00	162.11	164.19	0.93	0.00	0.00	0.90	1.83
	0.17	*1.09*	*0.00*	*98.73*	*100*	*50.64*	*0.12*	*0.00*	*49.23*	*100*
East	0.01	0.09	73.84	-	73.95	0.03	0.00	0.61	-	0.64
	0.02	*0.12*	*99.86*	-	*100*	*4.85*	*0.00*	*95.15*	-	*100*
Totals	0.32	1.89	86.61	162.11	250.93	0.99	0.00	0.77	0.90	2.67
	0.13	*0.75*	*34.51*	*64.60*	*100*	*37.13*	*0.09*	*29.04*	*33.74*	*100*

Percentages are in italic

From Table 2-4, it follows that the main flood sources for economic damage are Oostende (type D) and the harbours (type C). Together, these types represent over 99% of the total damage risk that is expected in the case of a severe storm surge. Expressed in absolute numbers, coastal flooding may cause a total economic damage of 25 million Euros per year in the coastal area. The Middle coast clearly runs the largest risk with about 16 million Euros per year (65%), in which Oostende has an extremely large share (99%). The East coast and the West coast respectively account for 7.4 and 1.3 million Euros (or 30% and 5%) to the annual damage risk. The map in Figure 2-5 depicts the areas along the coastline with a high economic vulnerability (that is, the total economic damage in these areas exceeds 90% of the total economic damage on the Belgian coast). Most vulnerable areas are clearly the

[4] The definition of flood source type D is the result of previous studies in which the city of Oostende was separately examined.

agglomeration of Oostende/Bredene, Middelkerke (which is flooded from the harbour of Nieuwpoort), Blankenberge and Zeebrugge.

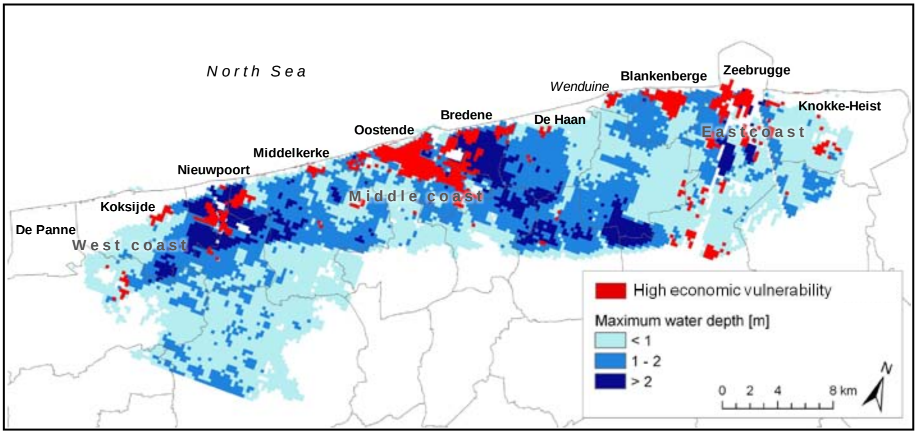

Figure 2-5 Indication of areas with a high economic vulnerability on the Belgian coast

A slightly different image is found for the casualty risks (cf. Table 2-4). Three flood source types are nearly equally important, namely flooding on the seawall due to overflow or dike breaching (type A; 37.1%), flooding in harbours (type C; 29%) and flooding in Oostende (type D; 33.7%). The large share by flood source type A is not surprising, given that the population density is prominent in the many apartment buildings that are located directly on the seawall. Analogous to Figure 2-5, Figure 2-6 shows the areas in the coastal area with a high social vulnerability (that is, the total number of casualties in these areas exceeds 90% of the total number of casualties on the Belgian coast). Notice the small line along the coastline which represents flood type A. The map further indicates that particularly the centres of Oostende and Bredene and the villages of Wenduine and Middelkerke account for the most casualty numbers.

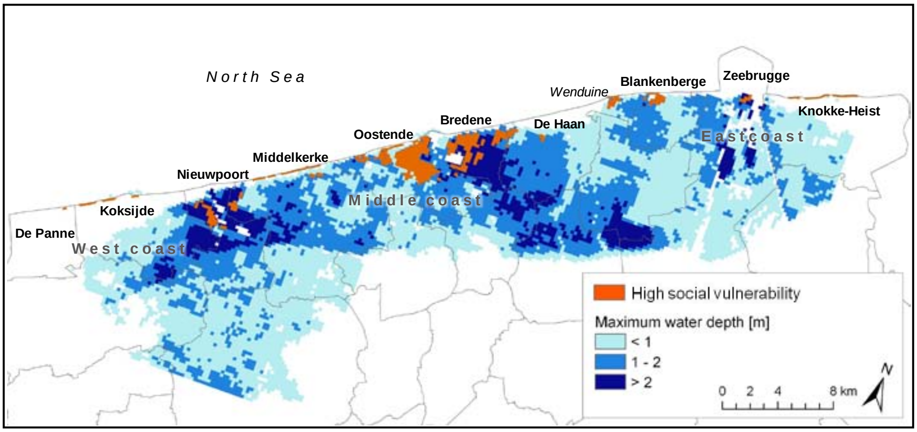

Figure 2-6 Indication of areas with a high social vulnerability on the Belgian coast

To conclude, it is clear from the above case study that some parts of the Belgian coast are more vulnerable to flooding than others. The risk calculations showed that in the case of a major storm, particularly Oostende may suffer from large economic damages as well as casualties. Other vulnerable locations are the harbours (Nieuwpoort, Blankenberge and Zeebrugge; economic damage) and Wenduine (casualties). Based on these – and more in-depth – findings, the Master Plan for Coastal Safety has concluded that about one-third of the Belgian coast is insufficiently protected against a 1,000-year flood. These locations will be prioritized in the future for additional defence measures, such as beach nourishment and dike heightening (Mertens 2010).

2.3 Future challenges

This section discusses the main challenges Flanders faces regarding the implementation of the European Floods Directive and the silent yet important call to communicate flood risks to the public.

2.3.1 European Floods Directive

The European Floods Directive (FD) aims to reduce and manage the flood related adverse consequences for human health, the environment, cultural heritage and economic activities. It therefore imposes on the European Member States that they should produce flood risk management plans by the end of 2015. These plans have to be preceded by producing a preliminary flood risk assessment by the end of 2011 and by producing flood hazard maps and flood risk maps by the end of 2013. After 2015, the flood risk management plans have to be updated every six years. The FD can be regarded as an extension to the European Water Framework Directive (WFD, 2000/60/EC), which had a primary focus on the development of river basin management plans to achieve a good ecological and chemical status.

Within the FD, flood risk management should concentrate on prevention, protection and preparedness. These components correspond with two of the four components of the emergency management cycle (FEMA, 2003), being prevention-mitigation (where protection can be seen as an equivalent of mitigation) and preparedness. Preventive actions to reduce flood probability can be spatial planning measures (e.g., no new human settlements within flood-prone areas) or the building of embankments as coastal defence measures. Preparedness can include risk communication for awareness raising, emergency planning and early warning. The two other components of this emergency management cycle are response (e.g., crisis communication) and recovery (e.g., insurance payments for rebuilding). Although the directive not literally requires that flood risk management plans focus on response, the directive demands that results are made available to the public. Moreover, active involvement of interested parties should be encouraged by the Member States when producing, reviewing and updating the flood risk management plans. This can be interpreted as a demand for more communication towards stakeholders (e.g., Hagemeier-Klose and Wagner, 2009; van Alphen *et al.*, 2009) and a demand for more flood risk management participation from citizens (e.g., White *et al.*, 2010).

Implementation of the Floods Directive in Flanders

Flanders faces two main challenges regarding the implementation of the FD: (i) the incorporation and quantification of intangible damage effects (health effects, environmental effects, cultural heritage); and (ii) the inclusion of other than river and sea-borne types of floods.

The current Flemish risk-based approach focuses on the tangible losses from flooding, being economic damage and casualty numbers. However, the FD requires that attention is also given to the assessment of health effects, environmental effects and effects on cultural heritage of flooding. These aspects have been taken into account for a social cost-benefit analysis in the Flemish Sigma plan (Broekx *et al.*, 2011), but not in a quantitative way. The measurement of these intangible effects will be a first challenge for Flanders. As Mostert and Junier (2009) already indicated, there exists very little experience about expressing these effects as quantitative measures. Research on health effects due to floods focuses mainly on the consequences of the overflow of sewage networks. These overflows result in an increase of bacteria, which can be assessed quantitatively (e.g., Karrasch *et al.*, 2009; ten Veldhuis *et al.*, 2010). Social studies on health effects are generally assessed qualitatively by questionnaires (e.g., Tapsell *et al.*, 2002; Tunstall *et al.*, 2006). Flood related environmental effects are not well studied, except for many regional environmental impact assessments (Mostert and Junier, 2009). Floods imply changes in water quality due to higher concentrations of heavy metals, biogenic elements and pesticides, resulting in a disturbance of vegetation cover and fauna (Istomina *et al.*, 2005). Flood effects on cultural heritage are in a way comparable to economic damage to buildings. However, damaged historic buildings or cultural heritage sites will never be comparable to the original situation. The first challenge is thus twofold: firstly, the quantification of the effects has to be achieved; secondly, these quantified effects have to be combined with the tangible losses from flooding. A possible way of combining these effects is a multi-criteria analysis. On-going projects, such as the FloodResilientCity (FRC) project, are making attempts towards an integrated approach of all effects (see www.floodresiliencity.eu).

The second challenge of the flood-approach is the incorporation of other types of floods than currently is the case. The FD (art. 2) defines a flood as 'a temporary covering by water of land not normally covered by water. This includes floods from rivers, mountain torrents, Mediterranean ephemeral water courses, and floods from the sea in coastal areas, and may exclude floods from sewage systems.' The current Flemish risk-based approach only takes into account river and sea-borne floods, while floods due to torrential rainfall or high ground water levels are also relevant (e.g., Kreibich *et al.*, 2009). Since hydrodynamic models are not (yet) available for these flood types, a pragmatic method will be first applied to incorporate these floods. A useful document in this regard will be the map with recently flooded areas in Flanders, which is constantly updated by the Flemish Authorities.

The Flemish situation in the European landscape

Compared with other EU countries, Flanders decided not to execute a preliminary flood risk assessment but to make the flood hazard and flood risk maps immediately. This strategy is also partly pursued by a number of neighbouring countries. Flanders particularly distinguishes itself from other European regions in the sense that it is integrating FD and WFD as from the first generation of river basin management plans (2009). The deadline for the flood risk management plans (FD) and the second generation of river basin management plans (WFD) is the same (2015). As such, Flanders is preparing one integrated plan suitable for both directives.

2.3.2 Towards active flood risk communication?

As mentioned earlier, the EU Floods Directive obliges the European countries to make their flood risk management plans available and accessible to the general public. While the Directive thus promotes passive communication, several researchers have interpreted this obligation as a first step towards active risk communication to the public (de Moel *et al.*, 2009; Hagemeier-Klose and Wagner, 2009).

Communicating flood risks to the public in a refined and understandable way may be crucial for a number of reasons (Rowan, 1991): (i) building trust in the communicator, (ii) raising awareness (e.g., of a potential flood hazard), (iii) educating, (iv) reaching agreement (e.g., on a particular strategy or investment plan) and (v) motivating action (e.g., precautionary measures against flooding of residence). Several researchers (e.g., Correia *et al.*, 1998; Bell and Tobin, 2007; Hagemeier-Klose and Wagner, 2009) have emphasized the role of flood risk communication to strengthen people's risk awareness and to motivate the population at risk to take preventive actions and to be prepared for an emergency case. Knowledge of the people's perceptions, preferences and needs may be essential to come to an effective risk communication (e.g., Keller *et al.*, 2006; Bell and Tobin, 2007; Kellens *et al.*, 2011b).

The recent years have witnessed a remarkable growth in the number of studies that have (at least partially) considered flood risk communication, for example COMRISK (2001-2005; Kaiser and Witzki, 2004), SafeCoast (2005-2008; Knolle *et al.*, 2007) and FLOODsite (2004-2009; Raaijmakers *et al.*, 2008). In addition, research networks such as CRUE ERA-net (Schanze *et al.*, 2008) and

CapHaz-net (Höppner *et al.*, 2010) have emphasized the role of risk communication in the context of flood hazards. A specific group of projects (e.g., EXCIMAP, RISKCATCH) has also examined how maps can be employed to communicate flood risks to the public. Because of their visual impact, flood maps are seen as ideal instruments to inform the general public about flood hazards and flood risks and strengthen people's risk awareness (EXCIMAP, 2007; Spachinger *et al.*, 2008). Moreover, the use of flood maps is also encouraged by the EU Floods Directive as a basis for flood risk management (de Moel *et al.*, 2009).

At present, Flanders lacks a large-scale active communication program regarding flood risks. The authorities sometimes disseminate flood (risk) related information via reports and leaflets, though these are mostly limited in edition and in spatial spread. Passive communication is realized through the availability of web maps with flood information. For river floods, web maps exist for both navigable and non-navigable waterways, providing actual information on water levels, water discharge and precipitation (cf. www.waterstanden.be; www.overstromingsvoorspeller.be). For several river basins, a 48-hour forecast can be consulted. As for coastal floods, no web maps are available to the public yet. Instead, Strategic Environmental Assessment (SEA) plans can be consulted by the public. These comprehensive plans contain information on various aspects of the measures that will be taken to reduce the flood risk. In addition, the first steps towards a participatory approach are being taken. This approach involves the organization of several workshops in which different aspects of the flood risk management planning are explained to the participants. To date, these participants are mainly professionals, but it is intended to involve the public in the future as well.

Flanders faces a number of challenges regarding active flood risk communication. First, it will need to further stimulate people's interest in flood related information, so that people are 'open' to it. Then, the communication will have to be delivered in a way that is understood. Keller *et al.* (2006) mention the problem for people of correctly interpreting risks with low probabilities but high consequences, such as flood disasters. Slovic (1987) showed that people care more about the number of people that is exposed to threats and the familiarity they have with the threat (experience), than paying attention to statistical probabilities. The communication will further have to address the heterogeneity of the public (Martens *et al.*, 2009), foster mutual understanding and mediate between different views (Höppner *et al.*, 2010). It will also be a challenge to deal with uncertainty which is inherent to risk assessment (Mostert and Junier, 2009; White *et al.*, 2010). Finally, the communication will have to be specific rather than generic, which means that communication should be adjusted to the specific needs of the people (Renn, 2005).

2.4 Conclusion

This chapter presented the state of the art of the Flemish risk-based approach regarding flood hazards. It showed that the current methodology is elaborate in the context of economic damage assessment and casualty calculations. Recent adjustments with regard to agriculture and land use have further improved the methodology. Two case studies demonstrated the usefulness of the methodology to support the decision-making process in choosing the best measures (cf. Yser study) or focus on the most vulnerable parts of a region (cf. coastal study). Both case studies further showed the major strength of the risk-based approach. As long as the approach is applied in a uniform way, relative values (percentages) provide reliable information to judge different situations and solutions. The detail level of the data plays a subordinate role in this regard (Apel *et al.*, 2009). On the contrary, absolute risk estimations should always be treated with certain circumspection, since they largely depend on the data and methodology that is employed.

Despite the qualities of the current Flemish risk-based approach, this chapter also demonstrated that there is still considerable work to do. Two main challenges follow from the requirements of the European Floods Directive, namely the incorporation and quantification of intangible damage effects (health effects, environmental effects and loss of cultural heritage) and the inclusion of other than river and sea-borne types of floods. The first challenge involves the development of a methodology to quantify intangible effects and to consequently combine them with tangible effects using multi-criteria analyses. The second challenge is in essence a demand for additional hydrodynamic models which are able to model other types of floods, such as rainfall and groundwater induced floods. Once these models are set, it will be a minor task to incorporate them into the risk methodology.

Although the European Floods Directive primarily focuses on the prevention-mitigation-preparedness aspects of the hazard life cycle, there exists a general call for more attention to response and recovery, as well as to flood risk communication. Whereas the Floods Directive requires flood risk management plans to be available to the public, more active flood risk communication is suggested by several researchers. This chapter showed that this aspect is underexposed in Flanders, though the first steps have been taken in that direction.

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3 COASTAL FLOOD RISKS AND SEASONAL TOURISM: ANALYSING THE EFFECTS OF TOURISM DYNAMICS ON CASUALTY CALCULATIONS

Modified from: *Kellens, W., Neutens, T., Deckers, P., Reyns, J., De Maeyer, P., 2011. Coastal flood risks and seasonal tourism: Analysing the effects of tourism dynamics on casualty calculations. Natural Hazards (in press - doi: 10.1007/s11069-011-9905-6)*

Abstract

Since coastal tourism is one of the fastest growing sectors of tourism industry, coastal areas have become increasingly vulnerable in the case of flooding. While in recent years a number of different methods have been put forward to map coastal flood risks, the implications of tourism dynamics for the assessment of human casualties has remained largely overlooked in these models. This chapter examines to what extent the ignorance of (residential) coastal tourism may bias the calculations of human casualties. To this end, a case study has been conducted on the Belgian coast. Both the dynamic nature of coastal tourism and the behaviour of residential tourists in storm surge scenarios are considered. The results of this study show that including tourism dynamics in flood risk management is justified and appropriate, depending on the tourist attractiveness of the flood-prone area and its temporal fluctuations.

3.1 Introduction

Coastal tourism is widely regarded as one of the fastest growing areas of the world's tourism industry (Miller, 1993; Hall, 2001). All over the world, coastal areas are developing rapidly and are attracting more and more tourists each year. The harmful impacts of coastal tourism on coastal environments have been discussed in depth in the academic literature (e.g., Bellan and Bellan-Santini, 2001; Burak *et al.*, 2004). However, the growth of the coastal tourism industry also generates challenges regarding climate change, sea level rise and flood risks: the more tourists in a coastal area, the higher the adverse consequences of a coastal flood. Coastal tourism can greatly influence the number of people exposed to a coastal flood hazard and consequently the number of fatalities or societal flood risk (Jonkman *et al.*, 2008). Moreover, several authors have suggested that tourists are more vulnerable than locals in disaster situations, because they are less independent and less familiar with local hazards and the resources that can be relied on to avoid risk (Burby and Wagner, 1996; Faulkner, 2001). Nonetheless, the effects of tourism have only scarcely been studied in coastal flood risk management. Traditional studies generally use fixed population data in their estimates of casualty numbers, but rarely account for effects of population dynamics such as tourism (Lentz, 2006).

Two data issues may be at the basis of this deficiency. Firstly, detailed spatiotemporal data are necessary to map out tourism fluctuations. Coastal tourism is a seasonal phenomenon, with variations according to climate, holiday seasons and seasonal traditions (Ahas *et al.*, 2007). The largest seasonal fluctuations are observed in tourist regions specialized in either winter or summer tourism. However, tourism dynamics may also fluctuate on a daily basis, for example due to the weather conditions, day of the week (weekday vs. weekend) and holidays. Secondly, there is a lack of tools to analyse tourist behaviour regarding storm and flood conditions. Research on tourism dynamics and tourist behaviour in the context of coastal flood risk management is limited to date.

This chapter addresses both issues by using detailed tourist census data to analyse the tourism dynamics on flood risk assessment in a case study on the Belgian coast. The main research question deals with the potential effects of these tourism dynamics on flood casualty calculations. How can we measure these effects and how should we interpret these? Using a GIS model endorsed by the Flemish government (Deckers *et al.*, 2010), casualty calculations are performed with tourist census data as input. An additional research objective addresses the expected behaviour of tourists in storm surge conditions. Are tourists inclined to continue their holiday plans or are they frightened by the potentially adverse effects of storms? Survey data are applied to answer this question. Outcomes are interpreted in a qualitative way, and consequences regarding casualty calculations are discussed.

3.2 Background

3.2.1 Societal risk and people at risk

Within the quantification of risks to people, results are generally expressed by individual risk and/or societal risk. Individual risk refers to the probability that an average, unprotected person is killed at a certain location, whereas the societal risk refers to the probability that a number of people of a given population are killed due to one event (Jonkman *et al.*, 2003). While the former approach is common practice in technical hazards (e.g., the dispersion of toxic gasses, fire, nuclear waste, etc.), the latter is more apposite to natural hazards such as floods and earthquakes. The estimation of the societal risk generally includes three phases (Jonkman, 2007):

1. The assessment of physical effects associated with the hazard, including the dispersion of the effects and the extent of the exposed area;
2. The determination of the number of people in the exposed area;
3. The estimation of the mortality and casualty number among the exposed population.

While phase 1 and phase 3 are strongly linked to engineering models, phase 2 is principally a spatiotemporal problem. The main focus in this phase is to find out who is exposed to a hazard, considering population dynamics. In literature, a distinction is often made between the concepts of registered population, people at risk and exposed population (Lentz and Rackwitz, 2004). The registered population N_{POP} are those people that are registered in the municipal. All individuals present in an exposed area are indicated as people at risk, often denoted as N_{PAR}. The actually exposed population N_{EXP} refers to all individuals that are exposed to the physical effects of the disaster. In order to estimate the population at risk (N_{PAR}), Lentz (2006) has identified three approaches: (i) the distribution-based approach, (ii) the object-based approach and (iii) the conditional distribution-based approach. The distribution-based approach relies on the registered population N_{POP} of a given area distributed over different buildings and locations as a function of time. This approach is usually applied for large-scale events, such as earthquakes or floods (Jonkman *et al.*, 2003). The object-based approach consists of counting all persons entering and leaving a building. Presence fractions can be defined to estimate the number of people in vulnerable buildings or locations (e.g., Mathijsen, 2003). The conditional distribution-based approach is a means of applying the distribution-based approach to single objects or groups of similar objects in an effective way without requiring additional data collection (as opposed to the object-based approach). Since the focus of this study is a large-scale flood event, the distribution-based approach is employed.

Jonkman *et al.* (2008) have argued that in large-scale applications with high population numbers, N_{PAR} can safely be approximated by the registered population in the area N_{POP}. In many cases, however, it might be essential to consider population dynamics to avoid crude over- or underestimations of the flood impact. The number of people at risk might, for example, be considerably smaller than the registered population when a part of this population is working outside the exposed area. Conversely, N_{PAR} might be larger when large numbers of tourists visit the area regularly. The effect of time on N_{PAR} is realized at three different levels (Lentz, 2006): time of day (i.e., working, sleeping, leisure times), day of the week (working/weekend day) and season.

While fluctuations at the level of daytime have been studied in prior risk assessment studies (e.g., McPherson *et al.*, 2004; Ahola *et al.*, 2007), the effects of tourism fluctuations which primarily occur at the level of day of the week and seasons have garnered far less attention. Therefore, the present study will explicitly focus on the effects of seasonal and day-to-day variations in tourist dynamics on coastal flood risk assessment. We will use N_{RT} to denote the time-dependent number of residential tourists on the Flemish coast. Assuming N_{POP} constant over the timescales considered, the population at risk N_{PAR} can then be formulated by:

$$N_{PAR}(t) = N_{POP}(c) + N_{RT}(t) \quad (1)$$

In this chapter, we will seek to account for this adjusted, time-varying number of people at risk.

3.2.2 Coastal tourism, dynamics and tourist behaviour

Coastal tourism can be defined as the full range of tourism, leisure and recreationally oriented activities that take place in the coastal zone and the offshore coastal waters, including accommodation, catering industry as well as tourism activities (e.g., swimming, recreational fishing and diving) (Hall, 2001). In this study, we use the term coastal tourism specifically for residential tourists in the coastal area, defined as tourists who stay at least two consecutive days on the Belgian coast. Day tourists as well as economic aspects of coastal tourism (e.g., accommodation, catering, etc.) are not considered in the present research.

Coastal tourism is subject to various dynamics, which are mainly characterized by seasonal variations. Such variations can be attributed to natural and institutional seasonality (Hartman, 1986). Natural seasonality refers to regular temporal variations in natural phenomena, particularly those associated with cyclical climatic changes throughout the year, such as temperature, precipitation, wind, and daylight (Butler, 1994). Braun *et al.* (1999) have found that good weather and plenty of sunshine are among the most important expectations regarding vacations. Climate and weather influence the attractiveness of a potential vacation region and require or enable certain kinds of facilities to be offered at the destination. Institutional factors are related to social norms and practices of society and are typically epitomized by holidays (e.g., industrial, school and religious holidays). Within this framework, tourism is seen to be constrained by work and other obligations (Higham and Hinch, 2002).

Although tourism seasonality is strongly linked to climate and weather conditions, the relationship between tourist behaviour and weather conditions may be not as straightforward as it may seem. For example, 'bad' weather conditions, such as storms, may not necessarily keep tourists away. Stormy weather above sea can result in spectacular overtopping of water along hard structures, such as rocks or dikes. This occurrence often attracts 'storm watchers' or 'storm chasers': people who are desired to observe and photograph the power of nature (Cantillon *et al.*, 1999). In this way, inquisitive tourists may become member of the exposed population themselves.

3.3 Study area

3.3.1 The Belgian coast: location and characteristics

The Belgian coast is located along the Southern Bight of the North Sea and measures 65 kilometres. It is characterized by sandy beaches, dune areas and hard defence structures such as groynes and seawalls. Apart from their main function as coastal protection infrastructure, seawalls also play a significant role in recreation (e.g., 'promenades' for coast-dwellers, bikers, skaters, etc.) and catering industry (e.g., popular spot for outdoor cafés). Due to the limited length of the coastline and the increasing population pressure, most of the coastal zone has become urbanized and half of the coastal dunes has disappeared (Charlier and Demeyer, 1995).

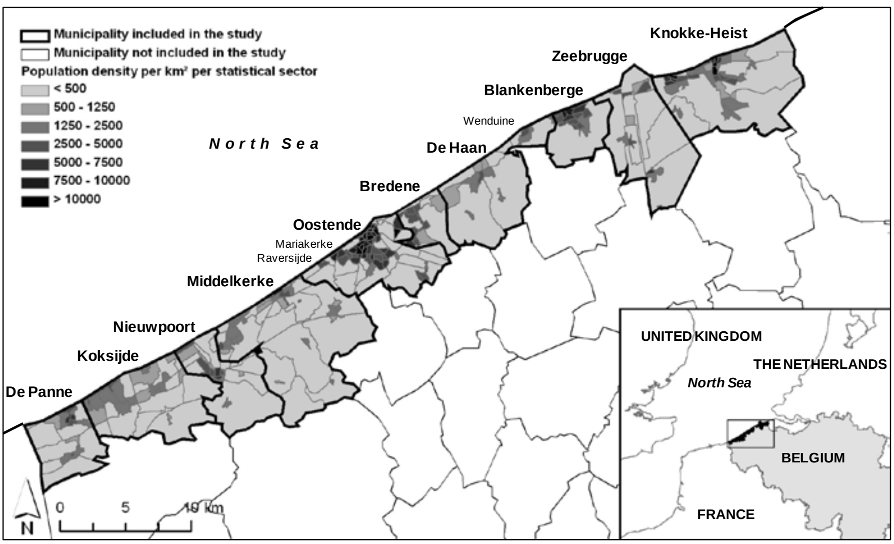

Figure 3-1 Location of study area

Figure 3-1 depicts the location of the ten coastal municipalities included in this study. Approximately 0.2 million people (2% of the Belgian population) live in this area. The mean population density amounts to more than 500 inhabitants per km², but in several statistical sectors[5] population density runs

[5] Statistical sectors are arbitrary areas used to aggregate socio-economic statistics. The origin of these sectors lies in the early 1970s, when the National Institute of Statistics (NIS, Belgium) was looking for a small territorial entity as a basis for socio-economic data. Sectors were chosen with equal morphologic and social characteristics. Hence, densely populated areas

up to thousands of people per km². The city of Oostende is with ca. 65,000 inhabitants the largest population centre on the Belgian coast, followed by Knokke-Heist (ca. 32,000 inhabitants) and Koksijde (ca. 20,000 inhabitants). The entire coastal area is attractive to many human activities, such as recreation, fishery, shipping, agriculture, trade, etc. Particularly the recreational attractiveness causes an increase in population with approximately 0.3 million residential tourists during summer (Lebbe *et al.*, 2008).

The high degree of urbanization and tourism activities make the Belgian coast extremely vulnerable to coastal flooding. It is therefore an intriguing area to study the relation between tourism dynamics and coastal flood risks.

3.3.2 Flood risks on the Belgian coast

In the past, several storm surges have affected the Belgian coast. During the severe storm flood disaster of 1953, eight people died in the city of Oostende. Since the record water level in 1953 (666 cm TAW), high water levels were measured in 1976 (590 cm TAW), 1993 (596 cm TAW) and 1997 (593 cm TAW). In the years ensuing the flood disaster of 1953, an important part of the Belgian seawalls was strengthened (Charlier and Demeyer, 1995). According to the outcomes of the Master Plan for Coastal Safety (Mertens *et al.*, 2010), today about one-third of the Belgian coast can be considered vulnerable to a coastal flood. Most vulnerable are the city centre of Oostende and the coastal villages of Raversijde, Mariakerke and Wenduine (cf. Figure 3-1 for their location). The Master Plan seeks solutions to cope with future coastal floods, considering climate change impacts until 2050. The project aims at protecting the coast against floods with a recurrence period of 1,000 years. Among the measures that are explored, beach nourishment and dike enforcements (e.g., building storm walls) are considered the most effective defence structures for the Belgian coast.

While coastal floods can be caused by various factors, such as windstorms, seismic activity (tsunami) and tidal waves (Jonkman, 2005), coastal flood risk management in Belgium is primarily focused on one plausible causer: windstorms. Northwesterly storms are particularly hazardous for the Belgian coast, since they push up the North Sea water towards the coastal areas. The situation becomes disastrous if these storms coincide with spring tide, which

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were split up in many small sectors, whereas larger sectors were created in rural – less populated – areas.

was the case in 1953 (McRobie *et al.*, 2005). In the low-land areas, windstorms occur mostly from October to April. However, even in the summer half of the year, storms remain possible. Exploratory POT-analyses (peak over threshold) on the Belgian coast revealed that the probability of an extreme storm is about five times larger during winter than during summer (analyses performed in the context of the Master Plan for Coastal Safety).

3.4 Data and methodology

3.4.1 Research approach

Figure 3-2 schematically presents the research approach that is employed in this study.

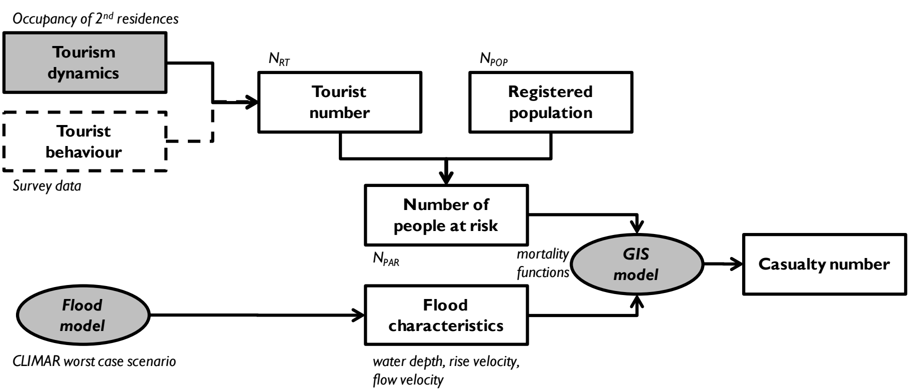

Figure 3-2 Flow chart of the research approach

First of all, the number of residential tourists on the Belgian coast (N_{RT}) is estimated through tourism dynamics, which are based on the occupancy of second residences. Tourist behaviour, measured through a field survey, is also linked to the tourist number, yet in a qualitative way (cf. Section 3.5.3). The addition of the registered population (N_{POP}) and the number of residential tourists gives the total number of people at risk (N_{PAR}). Furthermore, two models are employed in this study: a flood model and a GIS model. The flood model determines a set of flood characteristics (water depth, rise velocity and flow velocity) from a set of storm characteristics or assumptions (storm surge level, wave height). The flood model is based on the worst-case scenario of the BELSPO project CLIMAR. The GIS model ascertains the number of human casualties from these flood characteristics and the number of people at risk through mortality functions.

The next sections provide more information about the data sets and models which are grey coloured in Figure 3-2.

3.4.2 Location and occupancy of second residences

Within the framework of the Belgian coastal Action Plan (2005-2009), the research and consultancy office of West Flanders (WES) has held a large-scale survey with regard to the use and occupancy of second residences on the Belgian coast. About 5,100 inland and foreign homeowners were queried, representative towards country, region, municipality and time of the year. The WES survey filled up an important gap in coastal tourist data in Flanders since only a relatively small part of all nights on the Belgian coast is registered on a regular basis, leading to an underestimation of the tourist significance of the coastal area. In their study, WES defined second residences as private dwellings with recreational purposes which are included in the direct taxes. The owners of these second residences are not registered in the municipal and pay second residence taxes. For instance, apartments, villas, bungalows and studio flats, which are not used for professional purpose and do not have a first domicile on their address, are included in this study. Second residences represent about three-quarter of both the accommodation capacity and the total number of nights on the Belgian coast. The remaining quarter, which comprises accommodation in 'open air' (such as camp sites, holiday domains, etc.), hotels and other (e.g., accommodation for specific audience such as the elderly) is not considered in the WES survey. A second residence on the Belgian coast is occupied for 100 nights a year on average. The homeowner stays on average about 54 nights in his residence, lets about 15 nights to friends and family for free and lets about 31 nights to third parties (Gunst *et al.*, 2008).

The number of second residences on the Belgian coast is higher than in any other Flemish municipality. In 2007, 82,700 second residences were registered in ten coastal municipalities. Table 3-1 lists the number of second residences in each municipality. Previous counts of second residences (including holiday parks) show an increase of 23% between 1989 and 1997 and an increase of 16% between 1997 and 2007. This corresponds with a mean annual increase of about 2.4% or 1400 second residences over the period 1989-2007 (Gunst *et al.*, 2008).

Table 3-1 Number of second residences and portion per municipality (Gunst *et al.*, 2008)

Municipality	Number of second residences	%
De Panne	6,357	7.7
Koksijde	13,906	16.8
Nieuwpoort	8,315	10.1
Middelkerke	14,272	17.3
Oostende	6,717	8.1
Bredene	1,205	1.5
De Haan	6,732	8.1
Blankenberge	6,747	8.2
Zeebrugge	677	0.8
Knokke-Heist	17,772	21.5
Total 2007	82,700	100
Total 2007*	83,405	
Total 1997*	71,685	
Total 1989*	58,262	

*including residences in holiday parks

Figure 3-3 depicts the density of second residences per km² for each statistical sector. The highest concentrations of second residences are found in the statistical sectors bordering the coastline. About 70% of the second residences is located at a distance of less than 300 m from the coast.

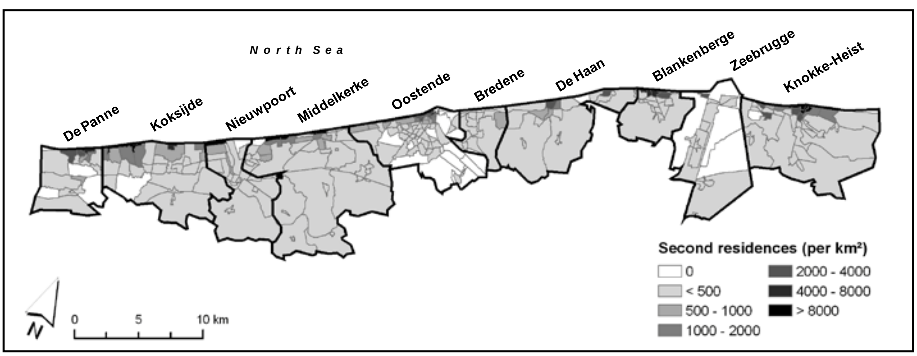

Figure 3-3 Number of second residences on the Belgian coast (per km²)

From the WES survey, three raw data sets are used in this study: (i) the number of second residences per statistical sector, (ii) the daily occupancy of second residences (June 2007 – May 2008) for the entire coast and (iii) the average number of persons per second residence (per municipality). From these data sets, the number of residential tourists N_{RT} is estimated per statistical sector for a given timescale (cf. Section 3.6.1).

Combining the number of second residences per statistical sector with the average number of persons per second residence, an estimated maximum of residential tourists $N_{RT(MAX)}$ can be defined. Figure 3-4 depicts the ratio of $N_{RT(MAX)}$ to the number of people at risk N_{PAR} per statistical sector. The map highlights those sectors where high percentages of tourists reside relative to the number of registered people. A significant part of the sectors adjacent to the coastline is touristy, but several sectors in the hinterland show high ratios as well. In the Results section, we will examine how these findings turn out with respect to flooding.

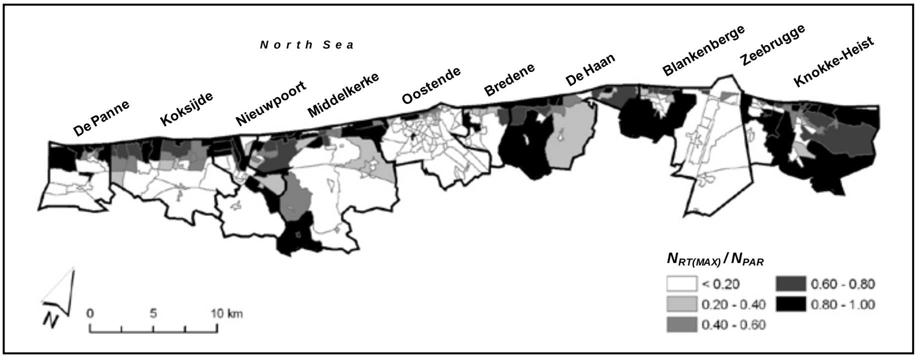

Figure 3-4 Ratio between the number of residential tourists (assuming all second residences are occupied, $N_{RT(MAX)}$) and the number of people at risk (N_{PAR})

3.4.3 Flood model

This study uses the results of a flood model that is currently in use in the framework of the Belgian BELSPO project CLIMAR (Van der Biest *et al.*, 2008). CLIMAR proposes adaptation techniques specific to the Belgian coast with regard to climate change and sea level rise. Two time horizons are studied in this context: 2040 and 2100. For both time horizons, WCS (worst-case scenario) flood models have been implemented for corresponding changes in hydrodynamic boundary conditions (Ponsar *et al.*, 2007). Since uncertainty levels are increasing enormously with prediction horizons, the model closest to the present is chosen. WCS 2040 is based on a maximum storm surge level of 8.71 m TAW and a significant wave height of 8.77 m (Reyns *et al.*, 2010). According to the model, this 'super storm' will cause dozens of dike breaches along the Belgian coast. Figure 3-5 shows the flood extents and water depths which are to be expected in the coastal region. The floods are mainly situated in two regions: Middelkerke/Oostende and Blankenberge/De Haan (Wenduine). Particularly in the low-lying city centre of Oostende, record water depths are estimated of ca. 4.9 m. Elsewhere, water depths vary between 0.2 and 1.5 m. The lines in the flood areas represent roads. The rectangular dark area south of Blankenberge is a very low-lying polder, originated from peat exploitation. Given the current climate change models, the estimated return period of this extreme flood scenario is about 7,000 years by 2040.

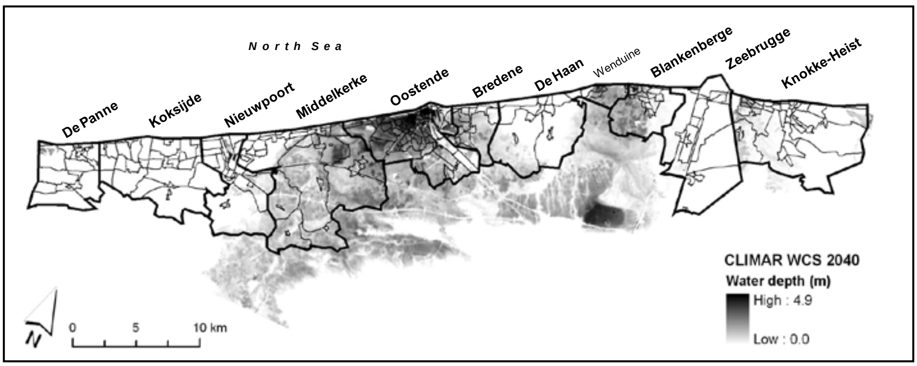

Figure 3-5 Flood extents and water depths according to the CLIMAR WCS 2040 flood model

3.4.4 GIS model

Since 2007, the Flemish government is using a GIS tool for the support of its flood risk management, called LATIS. The tool is developed by Ghent University and Flanders Hydraulics Research and functions as a shell around the raster based IDRISI software (Clark Labs). Based on the Flemish flood risk methodology (see Vanneuville *et al.*, 2006 for a comprehensive discussion), LATIS allows the user to perform risk computations for both economic losses and human casualties. Critical mortality parameters in the present methodology are water depth, rise velocity and flow velocity. The number of casualties is determined as a percentage of the number of inhabitants (N_{POP}). It grows exponentially with water depth and linearly with rise velocity and flow velocity (Deckers *et al.*, 2010).

In the present study, LATIS is used to calculate the casualties among the registered population (denoted as C_{POP}) and the casualties among the residential tourists (C_{RT}). The total number of casualties C_{TOT} is defined as the sum of C_{POP} and C_{RT}.

3.5 Results

3.5.1 Seasonal tourism on the Belgian coast

The WES survey data comprise estimated daily tourist numbers at the Belgian coast between June 2007 and May 2008. The 366 observations recorded within this period are aggregated into a number of categories, allowing us to work with meaningful scenarios. Eight separated scenarios are defined as follows: weekdays, weekend days, no holidays, holidays, spring days, summer days, autumn days and winter days. Based on these separated scenarios, 16 combinations are possible. It should be noted that the seasons are defined according to the generally accepted dates in the northern hemisphere: spring starts on 21 March, summer on 21 June, autumn on 21 September and winter on 21 December. Holidays comprise all official holidays (both religious and social) as well as school holidays for children younger than 18 years. These school holidays encompass 14 weeks a year: 8 weeks in summer (July and August), 1 week around All Saints' (November), 2 weeks around Christmas (December/January), 1 week around carnival (February) and 2 weeks around Easter (March/April).

Figure 3-6 depicts the mean occupancy of second residences with the corresponding number of residential tourists N_{RT} for each of the 16 time scenarios. Summer is obviously the most attractive season of the Belgian coast. It does not matter if it is weekday or weekend, holiday or not, the mean occupancy is always higher compared to the respective scenarios in spring, autumn or winter. On average, there are more second residences occupied during weekends than on weekdays, regardless of whether or not weekdays fall within a holiday period. As expected, the difference between the occupancy on weekdays and weekends is smaller during holidays than outside holidays. Furthermore, the mean occupancy of second residences is more or less similar in autumn and winter.

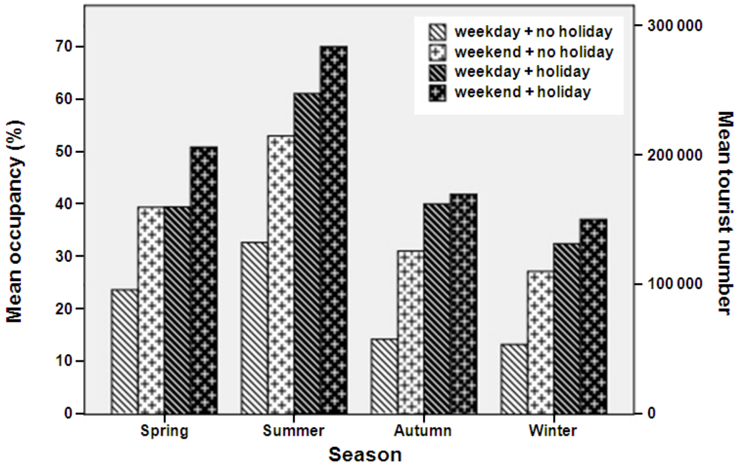

Figure 3-6 Mean occupancy of second residences and mean tourist number on the Belgian coast for various scenarios

With regard to the mean tourist number, we notice that weekend days and holidays attract on average about 250,000 to 280,000 tourists during summer. This corresponds to a mean occupancy of 61 to 70%. In spring, the maximum number of tourists is on average about 200,000. Except for summer, the mean tourist number does not exceed 100,000 during regular weekdays (no holidays) and does not exceed 200,000 during regular weekends (no holidays). One may notice that the mean occupancy during the winter is slightly higher than during the autumn. This is presumably because there are more holidays in winter relative to autumn. Moreover, the weather conditions in Belgium are traditionally better in winter (cold but stable) than in autumn (windy and rainy). The overall mean occupancy of the second residences on the Belgian coast is estimated at 32.5%, which corresponds to a daily mean tourist number of 130,000 people residing in the coastal area.

Employing a Scheffé post hoc test, significant differences were found between the mean tourist numbers in the four seasons ($p < 0.001$), except for the difference between autumn and winter, which is not significant ($p = 1$). Regardless of the season, the mean tourist number on weekdays or weekends differs significantly ($t = -7.32$, $df = 364$, $p < 0.001$, two-tailed), as well as on holidays or non-holidays ($t = -18{,}86$, $df = 184.28$, $p < 0.001$, two-tailed). An unplanned comparison on the combined scenarios revealed significant differences in mean tourist number between the combination 'weekday + no holiday' and 'weekend + holiday' ($p < 0.001$). However, no significant differences were observed between 'weekday + holiday' and 'weekend + holiday' ($p = 0.11$).

Summarized, coastal tourism fluctuations differ significantly between the summer half year and the winter half year, as well as on the level of day of week. Holidays play an unmistakably important role in occupancy of second residences. With these outcomes, we have found evidence for the significance of the factor time within N_{RT} (cf. Section 3.2.1).

3.5.2 Casualty calculations

The results of the LATIS computations are presented geographically in two figures. Figure 3-7 depicts the number of casualties per m² among the registered population (C_{POP}), Figure 3-8 represents the number of casualties per m² among the residential tourists on the assumption that all second residences are occupied ($C_{RT(MAX)}$).

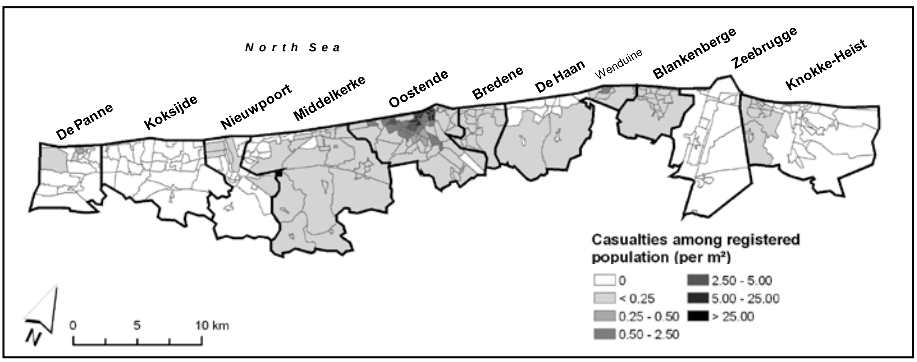

Figure 3-7 Casualties among registered population (C_{POP}, flood model: CLIMAR WCS 2040)

As for C_{POP} (Figure 3-7), it is clear that impact of the CLIMAR flood model is marked in the city of Oostende. Close to the coastline, several sectors indicate estimations of more than 25 casualties per km² among the registered population. Other noticeable impacts are observed in Wenduine, a small town near Blankenberge.

A slightly different image is obtained for the computations of $C_{RT(MAX)}$ (Figure 3-8). Compared to C_{POP}, C_{RT} is more pronounced in those sectors bordering the coastline. Marked impacts of the CLIMAR flood model are particularly observed in Oostende, Wenduine and De Panne. In Oostende, several sectors adjacent to the coastline indicate densities of more than 25 casualties per km². The centres of De Panne and Wenduine, both very close to the coastline, represent areas with densities over one and six casualties per km² respectively.

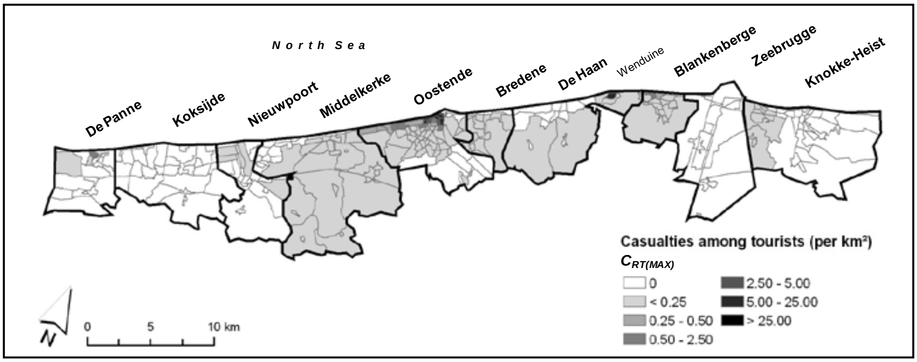

Figure 3-8 Casualties among tourists ($C_{RT(MAX)}$, flood model: CLIMAR WCS 2040)

Table 3-2 presents for each municipality the absolute numbers of the registered population (N_{POP}), the casualties among the registered population (C_{POP}), the maximum number of residential tourists ($N_{RT(MAX)}$) and the casualties among these tourists ($C_{RT(MAX)}$). Further, absolute numbers are presented for a summer and winter scenario. For both scenarios, the mean occupancy of the second residences was used (56.1% for summer; 21.4% for winter). We recall that the number of people at risk N_{PAR} equals the sum of N_{POP} and N_{RT} and that the total number of casualties C_{TOT} for both scenarios is defined as the sum of C_{POP} and C_{RT}.

On summer days, there are over 0.4 million people at risk in the ten coastal municipalities. More than half of them are residential tourists. In winter, tourists weigh less heavily on the total number. Then there are on average nearly 0.3 million people at risk, of whom 30% are residential tourists. The percentages in the N_{RT} column of Table 3-2 represent the portion of residential tourists (N_{RT}) against the total number of people at risk. Regarding tourism, the most vulnerable municipalities are Middelkerke (N_{RT}/N_{PAR} = 71.5%), Koksijde (N_{RT}/N_{PAR} = 67.8%) and Nieuwpoort (N_{RT}/N_{PAR} = 67.3%).

Least vulnerable are Bredene (N_{RT}/N_{PAR} = 19.9%) and Zeebrugge (N_{RT}/N_{PAR} = 15.7%). Figure 3-4 shows the spatial variations for a geographical output of the N_{RT}/N_{PAR} ratio at the level of the statistical sector.

For three municipalities - Nieuwpoort, Zeebrugge and Koksijde - few or no casualties are estimated. The WCS 2040 flood extents are negligible in these municipalities (cf. Figure 3-5). We ignore them in the remainder. The vast majority of casualties falls in Oostende (ca. 98%), followed by De Haan, Blankenberge and De Panne. The percentages in the C_{RT} column of Table 3-2 represent the impact of casualties among the residential tourists (C_{RT}) compared to the total number of victims for that scenario (C_{TOT}). We observe that the impact of C_{RT} is highest in the municipalities Blankenberge, De Haan and De Panne. In the summer scenario, 60.6 to 74.1% of the casualties are residential tourists. This percentage is lower in the winter scenario, but still more than 50% for De Haan and De Panne. The marked outcomes for De Haan are mainly due to the losses in Wenduine. In the municipalities Bredene, Knokke-Heist and Middelkerke, the impact of residential tourism on the total number of casualties is rather limited. The percentage of C_{RT} in the city of Oostende amounts to 36.3% in summer and 17.9% in the winter. These values are lower than in Blankenberge, De Haan and De Panne, but they represent hundreds of casualties.

In conclusion, marked outcomes are particularly observed in flooded sectors having a high N_{RT}/N_{PAR} ratio. This is mostly the case in those sectors adjacent to the coastline, which are also most vulnerable to flooding. The casualty calculations indicate that considering tourism dynamics can produce a significant impact, which can also vary significantly in time.

Table 3-2 Summary of casualty computations for each municipality

					Summer				Winter			
Municipality	N_{POP}	C_{POP}	$N_{RT(MAX)}$	$C_{RT(MAX)}$	N_{RT}	N_{PAR}	C_{RT}	C_{TOT}	N_{RT}	N_{PAR}	C_{RT}	C_{TOT}
Blankenberge	17,386	4.83	29,322	13.23	16,450	33,836	7.42	12.26	6,275	23,661	2.83	7.66
					48.6%		*60.6%*		*26.5%*		*36.9%*	
Bredene	12,633	3.90	5,602	0.25	3,143	15,776	0.14	4.04	1,199	13,832	0.05	3.95
					19.9%		*3.4%*		*8.7%*		*1.3%*	
De Haan	11,126	11.35	35,058	57.85	19,668	30,794	32.46	43.81	7,502	18,628	12.38	23.73
					63.9%		*74.1%*		*40.3%*		*52.2%*	
De Panne	9,870	2.42	31,149	14.50	17,475	27,345	8.13	10.55	6,666	16,536	3.10	5.52
					63.9%		*77.1%*		*40.3%*		*56.2%*	
Knokke-Heist	32,394	3.57	92,414	1.59	51,844	84,238	0.89	4.47	19,777	52,171	0.34	3.91
					61.5%		*20.0%*		*37.9%*		*8.7%*	
Koksijde	20,052	0.00	75,419	0.00	42,310	62,362	0.00	0.00	16,140	36,192	0.00	0.00
					67.8%		--		*44.6%*		--	
Middelkerke	16,503	3.04	73,775	1.89	41,388	57,891	1.06	4.10	15,788	32,291	0.40	3.44
					71.5%		*25.9%*		*48.9%*		*11.7%*	
Nieuwpoort	10,244	0.01	37,562	0.06	21,073	31,317	0.03	0.04	8,038	18,282	0.01	0.02
					67.3%		*85.9%*		*44.0%*		*70.0%*	
Oostende	65,688	1,906.04	28,887	1,939.45	16,206	81,894	1,088.03	2,994.07	6,182	71,870	415.04	2,321.08
					19.8%		*36.3%*		*8.6%*		*17.9%*	
Zeebrugge	91,68	0.00	3,047	0.00	1,709	10,877	0.00	0.00	652	9,820	0.00	0.00
					15.7%		--		*6.6%*		--	
Total	205,064	1,935.16	412,237	2,028.82	231,265	436,329	1,138.17	3,073.33	88,219	293,283	434.17	2,369.33
					53.0%		*37.0%*		*30.1%*		*18.3%*	

N_{POP} = registered population; C_{POP} = estimated casualties among registered population; $N_{RT(MAX)}$ = estimated maximum of residential tourists; $C_{RT(MAX)}$ = maximum number of casualties among the residential tourists (all second residences occupied); N_{RT} = number of residential tourists; N_{PAR} = number of people at risk; C_{RT} = estimated number of casualties among the residential tourists; C_{TOT} = total estimated number of casualties.

3.5.3 Tourist behaviour in stormy weather

Survey data are used to gain qualitative insights in the behaviour of tourists in stormy weather conditions on the Belgian coast. In a quasi-experimental design, residential tourists were asked to imagine two storm scenarios (A and B, cf. Table 3-3 for a verbal transcription of both scenarios) and express their degree of agreement on three items (1 item related to storm scenario A, 2 items related to storm scenario B, cf. Table 3-4).

Table 3-3 Verbal transcription of the two storm scenarios

Scenario A	*Assume you have booked a holiday week on the Belgian coast. On the day of your depart, radio and television are paying much attention to a heavy storm which will approach the Belgian coast in the next days. The Royal Meteorological Institute (KMI) predicts wind speeds over 75 km/h (> 9 Beaufort) and warns for large waves along the coast and dangerous situations on the dike promenades as a result of overtopping water.*
Scenario B	*A storm similar to the one in scenario A approaches the coast. Assume you are staying on the coast for holidays at the time you hear about this storm and the warnings.*

Table 3-4 Items for storm scenarios A and B

Storm scenario	**Item number**	**Item**
A	1	*I cancel my trip to the sea immediately.*
B	1	*I leave the coastal area immediately and go back home.*
B	2	*Stormy weather can cause spectacular pictures. I stay on the coast to watch the storm.*

The survey on tourist behaviour was part of a larger survey which probed the public's perceptions regarding coastal flood risks and coastal defence structures (see Kellens *et al.*, 2011). The overall response rate was approximately 20%. The sample that is used here consists of 175 residential tourists, of which 32% are women (N = 56) and 68% are men (N = 119). The sample's age ranges from 17 to 83 years (M = 56.8, SD = 13.8).

Table 3-5 presents the results of the questionnaire. As for scenario A, where the respondent is supposed to set off for a trip to the sea when weather forecasts predict major storms, we found that only 22% will cancel their trip immediately (A1). In scenario B, where the respondent is supposed to stay at the coast at the moment the storm is forecasted, about one-third of the respondents will leave the coastal area immediately (B1). Noticeably, almost half of the respondents answer that they would stay on the coast, just to watch the storm (B2).

Table 3-5 Questionnaire results on tourist behaviour in stormy weather

	No agreement		**Agreement**		**No opinion**	
	Number	%	Number	%	Number	%
A1 *(cancel trip)*	127	72.6%	41	22.3%	9	5.1%
B1 *(leave coastal area)*	117	66.9%	57	32.6%	1	0.6%
B2 *(storm watching)*	92	52.6%	78	44.6%	5	2.9%

The results of this questionnaire show that about two-third of the respondents are rather persistent in their holiday plans. The effect of 'storm watching' may contribute to this attitude. However, it should be acknowledged here that possible bias may occur due to the overrepresentation of male respondents in the sample. As previous studies have demonstrated (Kellens *et al.*, 2011; Ho *et al.*, 2008; Lindell and Hwang, 2008), men exhibit on average lower levels of risk perception than women. This lower risk perception often results in higher risk-taking behaviour (Jonkman and Vrijling, 2008). A second reflection deals with the uncertain correspondence between a person's stated intentions in a questionnaire, and his/her actual behaviour in case a major storm would be forecasted at the coast (cf. Kievik and Gutteling, 2011). Despite these limitations, the survey results provide reasonable grounds to assume that a fair part of the residential tourists will be present in the coastal area at the time a heavy storm reaches the coastline.

3.6 Discussion and conclusion

In this chapter, we have substantiated the inclusion of residential coastal tourism and its dynamics in societal flood risk, which is determined by the number of people at risk and the number of casualties expected in the case of flooding. A case study was conducted on the Belgian coast, a densely populated area characterized by a large tourism industry and a high vulnerability towards coastal flooding. A worst-case flood scenario was employed to analyse the effects of coastal tourism on casualty computations. The question as to what extent do tourism dynamics affect coastal flood risks shaped the main research objective of this chapter. An additional research objective dealt with the behaviour of these residential tourists in different storm scenarios.

The main research objective was addressed in two steps. Firstly, tourism dynamics were mapped out through a set of time-scaled scenarios based on day-to-day variations (weekday, weekend day or holiday) and seasonal fluctuations. Raw data reflected the occupancy rate of second residences (private dwellings with recreational purposes), from which the number of residential tourists (N_{RT}) could be determined. Significant differences were observed between the summer half year and the winter half year, as well as on the level of day of week and holidays. While we have made comparisons between different time settings, we were unable to consider peak occupancies. For example, nearly 70% of the second residences is occupied during weekends in the summer holidays (July-August), but the actual occupancy can easily run up to more than 80% in the week of the National holiday (July 21st). In winter, the average occupancy of second residences varies between 10 and 40%, yet peak occupancies of more than 50% are not impossible either (Gunst *et al.*, 2008). Secondly, the number of people at risk and the number of casualties in the case of a flooding were determined. It was shown that the number of people at risk (N_{PAR}) in the summer is twice as large than if only the registered population N_{POP} is taken. In winter, N_{PAR} is almost 30% more than if only N_{POP} is used. As mentioned earlier, these outcomes are average estimations. Peak occupancies can inflate N_{PAR} considerably. Casualty calculations were conducted for a worst-case scenario (in which all second residences are supposed occupied) and two time-scaled scenarios (mean tourist number on a summer and a winter day). A worst-case flood scenario (CLIMAR WCS 2040) served as flood model within the Flemish GIS tool LATIS, which uses water depth, flow velocity and rise velocity as mortality parameters. This flood scenario is expected to cause numerous dike breaches on the Belgian coast and will particularly affect three locations: Oostende, Wenduine and De Panne. Especially in Oostende, marked spatial differences were observed between the location of the casualties among the registered population and among the residential tourists. Whereas the former group is mostly situated in the centre of the flooded city, the latter group is particularly located in those sectors adjacent to the coastline. The main cause of this distinction may be the urban morphology of the Belgian coast, which is characterized by high percentages of second residences near the coastline and lower percentages in the centres of the municipalities.

An important note concerns the relative frequency of extreme storm surges. We recall that on the Belgian coast, according to preliminary POT-analyses, the probability of a winter storm is about five times larger than a summer storm. While these frequencies do not affect the casualty calculations reported above, they do affect the corresponding risk values. Hence, in terms of risks, winter casualties should receive a weight factor of 5 in order to meaningfully compare them with summer casualties (which would then receive a weight factor of 1).

Concerning the second research objective, qualitative interpretation of survey data suggested that residential tourists are rather persistent in their holiday plans, irrespective of storm forecasting. Moreover, several tourists indicated that they would stay on the coast just to watch the storm surge, an outcome which supports previous studies on 'storm watching' behaviour (Cantillon *et al.*, 1999). This risk-taking behaviour was recently observed on the Belgian coast during the severe storm of 28 February 2010. Without knowing the consequences of the storm in France (where more than 50 people died in coastal floods), dozens of people visited the Belgian coast. They explained to the media that they were looking for 'nature power'. Based on the results of the questionnaire, we believe that a fair part of the residential tourists – about two-third – will be present at the coastline in case a heavy storm hits the coast. However, possible survey biases with regard to sample representativeness (overrepresentation of men) and unknown correspondence between intentions and actual behaviour yield uncertainty in this outcome. Future research could lower these uncertainties by employing an experimental study design in which more items are used to measure the respondent's intentions.

Some general limitations of the study need to be addressed. A first limitation concerns the level of detail of the census data. Although this data set has a fairly high degree of temporal detail (the occupancy of second residences is known for each day for the period of one year), the spatial resolution is limited to the scale of the entire coastal area. It was therefore not possible to consider spatial variations within the municipalities over time. Other data sets, such as mobile positioning data obtained via GPS devices and mobile phones, might meet this detail level. Recently, several researchers have explored the possibilities of these data sets, for example Ahas *et al.* (2008), Song *et al.* (2010) and Byon *et al.* (2009). In Belgium, as in many other countries, mobile positioning has already been applied successfully to track vehicles and estimate traffic jams. For the most part, however, the data are not yet available for accurately tracking the position of individuals who are not travelling within transport networks (e.g., in buildings, parks, etc.). A second limitation is the assumption of a constant N_{POP}. The registered population mainly fluctuates at the level of day and week as a consequence of inter alia work and leisure activities (Lentz, 2006). Previous research on natural disasters and technical hazards proposed ways to determine these N_{POP} fluctuations (Glickman, 1986; Aboelata and Bowles, 2005; Ahola *et al.*, 2007), though applying these methods often remains difficult. For instance, in the context of flood risks due to dam failure, McClelland and Bowles (2000) have suggested to consider temporal aspects for a number of homogeneous population groups, such as motorists, train passengers, people living in buildings, etc. However, while valuable at the conceptual level, these refinements become compromised when greater generalizability is desired. A third limitation that should be addressed in future research is the neglect of the effects of evacuation possibilities on population dynamics. Evacuation is defined by the movement of people from a (potentially) exposed area to a safe location outside the area before they come into contact with physical effects (Jonkman *et al.*, 2008). While specific evacuation models have been developed for floods (e.g., LIFESim - Aboelata and Bowles, 2005; Evacuation Calculator - Van Zuilekom *et al.*, 2005), they are difficult to apply in real-world situations given the severe data requirements. Assessing evacuation in flood risk management encompasses the determination of several parameters, such as available time, time required for evacuation, population characteristics (e.g., age, mobility) and road network characteristics (e.g., road density, road capacity, congestion points).

Despite these limitations, the outcomes of this study have clearly foregrounded the implications of accounting for coastal tourism dynamics in flood risk calculations. However, the question remains to what extent the increased insights that can be obtained by the incorporation of tourism dynamics justifies the extra data requirements and computational efforts? If the flood-prone area is as touristy as the Belgian coast, it may certainly be justified. The study showed significant temporal variations in coastal tourism dynamics leading to important impacts on coastal flood risk calculations. However, our research did not only result in improved casualty calculations. It also pointed out that there is a spatial, temporal and behavioural vulnerability of coastal tourism towards floods. From a spatial point of view, coastline areas tend to be most vulnerable to storm surges such as overtopping water and dike breaching, given that the majority of the tourists reside nearby the coastline. Temporal variations in tourism can cause peak moments which make tourists extra vulnerable to flooding. Third is vulnerability induced by behaviour during storm surges. A major part of the tourists is not frightened by bad weather and may consequently reside on the coast at the time a flood happens. Although effects may differ between coastal areas, we believe that flood risk management should always verify possible tourism effects. Moreover, the study of tourism dynamics should not be restricted to coastal flood risks. Since mountainous areas are also attractive to tourists, considering tourism dynamics in mountain flash floods could be important as well. Taken together, we hope that our study will stimulate a more careful consideration of the implications of tourism dynamics in flood risk management.

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4 PERCEPTION AND COMMUNICATION OF FLOOD RISKS: A LITERATURE REVIEW

Modified from: *Kellens, W., Terpstra, T., Schelfaut, K., De Maeyer, P., 2011. Perception and communication of flood risks: A literature review. (submitted for publication in Risk Analysis)*

Abstract

Flood hazards are the most common and destructive of all natural disasters. For decades, experts have been examining how flood losses can be mitigated. Just as in other risk domains, the study of risk perception and risk communication has gained increasing interest in flood risk management. Because of this research growth, a review of the state of the art in this domain is felt necessary. The review comprises 57 empirically based peer-reviewed articles on flood risk perception and communication from the Web of Science and Scopus databases. The characteristics of these articles are listed in a comprehensive table, presenting the author, flood type, study location, survey and analysis methods, sample size, theory and the variables that were studied. From this review, it follows that the majority of studies are of exploratory nature and have not applied any of the theoretical frameworks that are available in social science research. Consequently, a methodological standardization in measuring and analysing people's flood risk perceptions and their adaptive behaviours is hardly present. This heterogeneity leads to difficulties in comparing results between studies. It is also shown that theoretical and empirical studies on flood risk communication are nearly nonexistent. The chapter concludes with a summary on methodological issues in the fields of flood risk perception and flood risk communication and proposes an agenda for future research.

4.1 Introduction

Flood hazards are a serious threat to the economic and social structures of our society. Each year, floods claim around 20,000 lives and adversely affect at least 20 million people worldwide, mostly through homelessness (Smith and Petley, 2009). Recent studies have indicated that the losses from flood hazards are expected to increase in the upcoming years. This prognosis is mainly based on the predicted impacts of the climate change (Nicholls *et al.*, 2007). In many countries, however, flood vulnerability is also expected to increase as a consequence of population growth and spatial expansion (Siegrist *et al.*, 2006). Around the world, flood risk experts and decision-makers face the challenge to find techniques and measures to effectively cope with these hazards. In order to assess the negative impact of flood hazards, experts have gradually adopted a risk-based approach, which focuses on the probability of events and the magnitude of negative consequences (Merz *et al.*, 2010). While this technical approach deals with *objective* risk assessment, a substantial group of researchers have concentrated on the *subjective* aspects of flood risk, which determine people's risk perception. Several researchers recognize that flood risk management is shifting from a primarily objective approach to an integrated approach with attention to social aspects such as improving flood preparedness and response (Terpstra and Gutteling, 2008; Botzen *et al.*, 2009a). As such, the need to integrate lay knowledge into measures to prevent, mitigate and deal with risk is a relatively new field of research (Figueiredo *et al.*, 2009). Risk communication is becoming increasingly propagated as an essential measure to fulfil these needs (Renn, 2005).

Previous articles have reviewed the general evolution of risk perception and communication (Fischhoff, 1995), comparative studies in risk perception (Boholm, 1998) and risk communication to the public (Bier, 2001). Up to now, however, no review article has covered the findings of risk perception and risk communication in flood risk research. As a result of the increasing attention for flood risk mitigation and the application of risk perception and risk communication in this, an overview of the state of the art in these domains is felt necessary.

This review chapter is organized as follows. Section 4.2 presents background information on the origins of risk perception and risk communication. Sections 4.3 to 4.7 provide an overview and discussion of a set of empirically based peer-reviewed articles in the domains of flood risk perception and flood risk communication. Attention is successively given to the selection of the studies, general trends in the research domain regarding bibliometrics and study area, the survey and analysis methods that have been used, the theories that have been applied and developed, and the empirical findings that have been found. Finally, Section 4.8 provides a compact discussion and proposes an agenda for future research in the domain.

4.2 Background

4.2.1 Risk perception

The beginning of the research on risk perception is situated in the 1940s, when Gilbert White published his ground-breaking thesis on human adjustments to floods in the United States. White (1945) found that people's flood experience directly influenced their behaviour when they were under threat from a possible flood. With his work, White pioneered the way for research on the human dimension of risk in multi-hazard environments (Brilly and Polic, 2005; Bird, 2009). In the 1960s, risk perception appeared on the stage of political agendas since it was considered as a main determinant of the public opposition to new technologies, in particular nuclear technology. Based on the analysis of historical data, Starr (1969) discovered a systematic relation between the acceptance of technological risks and the perception of costs and benefits from these technologies. It seemed that society accepted risks to the extent that they were associated with benefits (Sjöberg *et al.*, 2004). While this method of exploring revealed preferences resulted in new insights, questions arose about its objectivity, since findings are strongly compliant by the interpretation of the researcher (Craye *et al.*, 2001). In the subsequent decades, risk perception research evolved to psychological experiments and public surveys, in which people's perception could be assessed with expressed preferences. This evolution led to the development of several theories and approaches, some of which will be illustrated in more detail in Section 4.7.

4.2.2 Risk communication

Covello *et al.* (1986) define risk communication as any purposeful exchange of information about health or environmental risks between interested parties. Trettin and Musham (2000) clarify these parties as either individuals, groups or organizations. Risk communication covers a wide range of activities, such as stimulating interest in environmental health issues, increasing public knowledge, influencing attitudes and behaviour of people, acting in situations of emergency or crises, aiding in decision-making and assisting in conflict resolution (Boholm, 2008) In his White Paper on Risk Governance, Renn (2005) underlines the importance of adjusting risk communication to the specific needs of the people. In this way, people are facilitated to judge their own risk situation and to make informed decisions according to preparedness and personal safety measures. Effective communication, or the absence of it, may have a major bearing on how well people are prepared for a disaster (Basic, 2009).

According to the definition of Covello *et al.* (1986), risk communication should aim for a bidirectional exchange of information. However, this bidirectional exchange has not always been considered the key to effective risk communication. The early rationale for risk communication research derived from the identified distinction between the scientific way to assess risk (based on calculations of probability and estimated 'loss') and the lay people approach which tended to over- or underestimate risk (Boholm, 2008).

Over the last two decades, risk communication has gradually evolved to a two-way communication process in which both the public and the risk managers are expected to engage in the social learning process (Renn, 2005). Today, it is widely recognized that public values and preferences must be included in risk assessment and management (Renn, 1998; Boholm, 2008). Emphasis has shifted from a pedagogical approach to deliberation, dialogue and public participation. The normative theory of communicative rationality advocates this dialogue between actors who are willing to listen to each other and who are open to change their minds and positions on a certain issue depending on how the deliberative process unfolds (Habermans, 1985). To obtain a successful dialogue, mutual trust is needed between the actors (Petts, 2008). However, as Pidgeon (1992) mentioned, 'trust is hard to gain, but easy to lose'.

4.3 Selection of studies

During November-December 2010, an extensive literature search was conducted on the electronic online databases Web of Science (www.isiknowledge.com) and Scopus (www.scopus.com). Web of Science is a well-regarded database, which – according to the database publisher – provides seamless access to multidisciplinary coverage of over 10,000 high-impact journals in the sciences, social sciences, and arts and humanities, as well as international proceedings coverage for over 120,000 conferences. Scopus is a relatively new but rapidly expanding database, and claims to be the largest abstract and citation database containing approximately 17,000 peer review journals.

Four rules were applied to our literature selection: (i) the work is peer-reviewed in an international journal, (ii) the research is based on empirical data, which relate to citizens or at least partly to citizens, (iii) the research is applied to flood risks in general or to a specific type of flood risk (e.g., river -, flash -, coastal -, etc.), and (iv) the public perception of or the public attitude towards flood risks is measured (either qualitative or quantitative) or specific attention is given to the communication of these risks. In order to find as many articles as possible in this context, the following search key was designed:

(flood OR hazard*) AND (perception* OR perceiv* OR attitude* OR communicat*)*

The use of an asterisk allowed finding articles with 'flood', 'floods' or 'flooding', 'perception' or 'perceived', 'communication' or 'communicated' and 'attitude' or 'attitudinal' in their title, keywords or abstract. The word 'hazard' was used to capture also articles that would refer to floods as 'natural hazard' or 'environmental hazard'. The gross number of articles found in both databases (Web of Science and Scopus) was 642 (269 and 373, respectively). By removing 105 duplicates, the net number was reduced to 537 studies. However, it was clear from the title alone that about 80% of these articles did not fit the four rules. Although the words 'floods', 'perception' or 'communication' were used in these articles, their meaning was unrelated to this study's social/psychological perspective (e.g., 'The chemical expression of biotic and abiotic processes occurring in the Amazonian floodplains can be particularly perceived during falling waters') and in some cases the word 'flood' even meant something totally different (e.g., 'Flooding is a commonly used technique for network resource and topology information dissemination in the data communication networks'). Deleting these non-intended hits further reduced the number to 114 articles. In a final step, the authors independently and carefully reviewed all the 114 abstracts by applying the four rules. Conflicts and doubtful cases were discussed before a decision was made. Some abstracts did not contain sufficient information for these selection criteria, so full papers were then analysed. Twenty-five articles were omitted because they were not based on empirical data (selection rule 2). Another thirty-seven studies were removed from the list since they did not measure (neither qualitative nor quantitative) the public perception of flood risks (selection rule 4). Strict implementation of selection rule 4 resulted in the omission of a set of articles on mental health issues and psychological impacts (e.g., post traumatic stress syndrome) resulting from flood experiences. Fifty-two studies remained after this in-depth review. Eventually, the set of articles was extended with two recently published articles (which were not yet taken up in Web of Science or Scopus at the time of the literature search) and three articles in press. As such, the final selection comprised 57 articles.

Table 4-1 in Appendix presents this selection of papers with following characteristics: (i) author and year, (ii) study area and flood type, (iii) survey method, number of respondents (N) and analysis methods, (iv) the theory that was applied (if any), (v) how flood risk perception was measured, (vi) behavioural variables regarding mitigation and preparedness, (vii) physical exposure variables and demographics, and (viii) other important variables. The following sections each discuss one or more of these columns in more detail.

4.4 General trends

4.4.1 Bibliometrics

This section discusses bibliometrics regarding publication year, journal and author of the selected articles.

As Figure 4-1 depicts, there is a marked increase in the number of studies on flood risk perception in recent years. Only eight of the 57 studies have been published before 2005; as much as 49 studies have been published since 2005. Three studies in press (Kellens *et al.*, 2011; Pagneux *et al.*, 2011; Terpstra, 2011) are expected to be published in 2011. Noteworthy is the lower number of articles in 2010 compared to 2008 and 2009. This is probably a coincidence, and not the herald of a decrease of studies in the field.

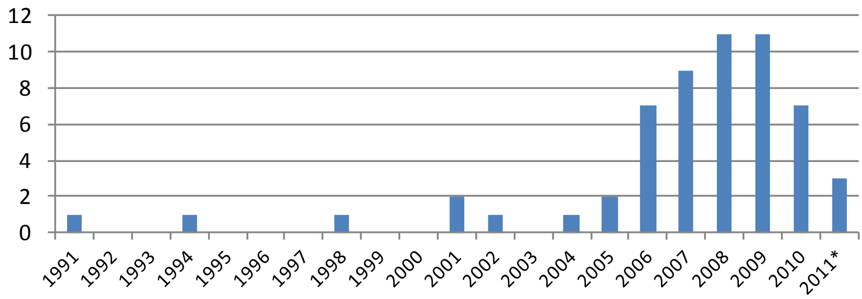

Figure 4-1 Number of publications per year (* the number of publications in 2011 is provisional)

Figure 4-2 presents the number of publications by journal. The 57 studies were published in 24 different journals. Leading journals in the domain of flood risk perception are *Risk Analysis* (15 publications), *Natural Hazards* (8 publications), and *Natural Hazards and Earth System Sciences* (6 publications). *Journal of Risk Research* and *Environmental Hazards* both have three publications. All other journals (19) have published only one or two studies published in the field. This shows that perception research on flood risks is more supported by journals related to environmental risks and hazards than by journals related to psychological or health issues.

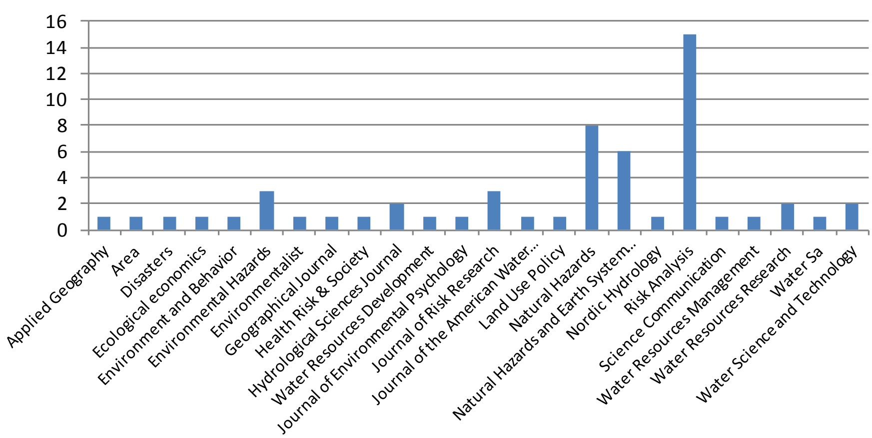

Figure 4-2 Number of publications by journal

Figure 4-3 shows the number of publications by author, either as first author or co-author (only authors with two or more publications are shown). Productive authors in the domain of flood risk perception are Terpstra, Kreibich and Thieken (each with four publications). Eight researchers have two or more publications as first author: Terpstra (4), Zhai (3), Botzen (2), Krasovskaia (2), Kreibich (2), Lopez-Marrero (2), Siegrist (2) and Thieken (2).

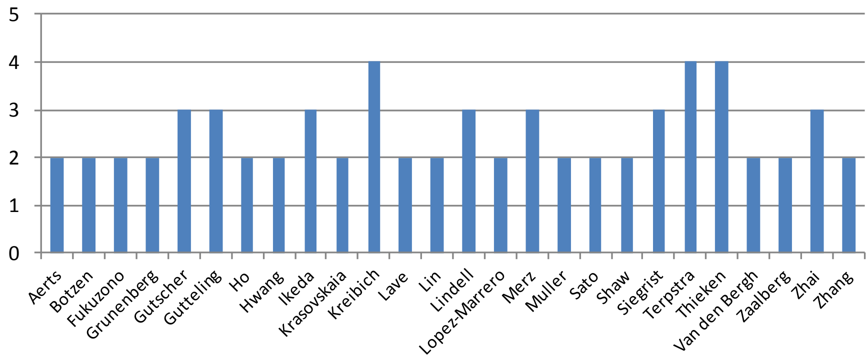

Figure 4-3 Number of publications by author (either as first author or co-author)

4.4.2 Study area and flood type

The study of flood risk perception is paramount in the western world. Europe is well represented by 34 studies, followed by North America (10 including Puerto Rico) and Asia (10). In Europe, most studies have their study area in the Netherlands (7), Germany (7), United Kingdom (4), Spain (3) and Switzerland (3). North America does only count research from the United States (8) and Puerto Rico (2). In Asia, most studies come from Japan (4) and Taiwan (3). The Southern Hemisphere is strongly underrepresented in literature. Our search revealed only two studies that were conducted in Africa (Nigeria and South Africa) and none in South America and Oceania. The only study with an international study area is Krasovskaia *et al.* (2007) with focus on the countries surrounding the North Sea (Germany, the Netherlands, Norway, Sweden and United Kingdom).

Regarding flood type, it should be noted that it was often difficult to identify the type under study. Some studies clearly mentioned the flood type, but in other studies, the flood type could only be derived from the study area. Some researchers focused on just one type, others explored multi-flood types. In a number of studies (15), it was not possible to determine any flood type. In Table 4-1, main distinction is made between river, coastal and flash floods. Most studies in flood risk perception research deal with river floods (26). Studies on flash floods (9) and coastal floods (8) form a smaller group. Three single studies examined specific flood types, namely groundwater flooding (Kreibich *et al.*, 2009), sewage flooding (Arthur *et al.*, 2009) and muddy floods (Heitz *et al.*, 2009). While some of these flood types entail a specific cause (e.g., sewage flooding as a consequence of sewage malfunction), general flood causes such as rainfall, storm surge, typhoon/hurricane, are often not reported. Seven studies examine other hazards next to flood risks, such as landslides (Wagner, 2007; Ho *et al.*, 2008; Lin *et al.*, 2008), earthquakes (Ge *et al.*, 2010) and chemical releases (Lindell and Hwang, 2008).

4.5 Survey methods

All but two studies conducted a cross-sectional survey on respondents. This study design involves observation of all of a population, or a representative subset, at a defined time (Saunders *et al.*, 2006). Keller *et al.* (2006) and Terpstra *et al.* (2009) have used (quasi-)experimental designs, in which respondents are surveyed under controlled circumstances. Choosing the appropriate survey method encompasses numerous decisions regarding questionnaire characteristics and sampling technique.

4.5.1 Questionnaire characteristics

In order to measure or grasp the perception, attitude or behaviour of people, a well-developed questionnaire is of paramount importance. While it is encouraged to reuse approved or standardized questionnaires in surveys (Lindell and Perry, 2000; Bird, 2009), it seems that most researchers in flood risk perception studies develop their own questionnaires (e.g., Brilly and Polic, 2005; Siegrist *et al.*, 2006; Terpstra *et al.*, 2006; Ali, 2007; Benight *et al.*, 2007; Armas and Avram, 2009; Heitz *et al.*, 2009; Hung, 2009; Lara *et al.*, 2010; Lopez-Marrero and Yarnal, 2010) or adapt questionnaires from other work to fit their specific needs (e.g., Kreibich *et al.*, 2007; Thieken *et* *al.*, 2007; Raaijmakers *et al.*, 2008; Terpstra *et al.*, 2009; Kellens *et al.*, 2011). Few studies report that their questionnaires had been tested, for example by focus groups (Armas and Avram, 2009), households (Zaalberg *et al.*, 2009), or experts (Krasovskaia, 2001; Benight *et al.*, 2007; Botzen *et al.*, 2009b). Even in theoretically-based research, studies make (small) adaptations to the questionnaire. For example, Ge *et al.* (2010) and Lin *et al.*(2008) employed the Psychometric Paradigm for their research, yet the applied items to measure risk perception differ between both studies (cf. Section 4.7.1).

As far as it is indicated, the majority of the studies employ both closed and open questions. Closed questions produce results that are easily summarized and translatable into statistical models while open questions produce verbatim comments adding depth and meaning (Bird, 2009). As Table 4-1 depicts (column 'Analysis method'), the majority of the studies focuses on quantitative analyses (QN), though several studies explicitly combine these analyses with a qualitative approach (e.g., McEwen *et al.*, 2002; Heitz *et al.*, 2009; Lopez-Marrero and Yarnal, 2010). The other studies mostly use open questions uniquely to interpret results and discuss on findings.

Although the majority of the studies does not specify the number of questions in their survey, it seems that this number generally lies between 20 and 40 questions (e.g., Armas and Avram, 2009; Heitz *et al.*, 2009). Extreme cases are the studies of Siegrist and Gutscher (2006) and Thieken *et al.* (2007) who have utilized a questionnaire with 110 and 180 questions respectively. Though there are no strict rules for length and duration of a questionnaire, Saunders *et al.* (2006) have reported that the number of questions in a survey is negatively correlated with the response rate. A questionnaire should contain as many questions as necessary and as few as possible (Sarantakos, 2005).

4.5.2 Sampling technique

In order to obtain a representative sample, most studies have endeavoured a probability method, such as simple random (Heitz *et al.*, 2009; Horney *et al.*, 2010), stratified sampling (Lopez-Marrero and Yarnal, 2010) or cluster sampling (Horney *et al.*, 2010). Whereas in simple random sampling each individual of the population has an equal chance of being selected (e.g., by random selection of telephone numbers), stratified sampling considers subgroups or 'strata' of individuals which are mutually exclusive (e.g., strata based on resource endowment such as lower, intermediate and upper income). Cluster sampling differs from stratified sampling in that its groups or clusters are based on natural groupings. Each cluster is then treated as the sampling unit, i.e., analysis is done on populations of clusters (Saunders *et al.*, 2006). Despite the importance of the sampling method regarding representativeness of the sample, only a minority of the studies reports on the method of sampling.

Regarding target group, most studies simply address the general public, whether or not located in a flood-prone area (e.g., Armas and Avram, 2009; Figueiredo *et al.*, 2009). Some studies specify the target group, such as farmers (Heitz *et al.*, 2009), homeowners (Botzen *et al.*, 2009a) and flood victims (Whitmarsh, 2008). Other studies also survey non-public groups such as local authorities (Ge *et al.*, 2010) and decision makers (Correia *et al.*, 1998).

As far as delivery method is concerned, Bird (2009) distinguishes between self-administered and administered methods. Among the self-administered methods, questionnaires can be distributed either via mail or email. Despite the increasing interest in on-line questionnaires (e.g., Knocke and Kolivras, 2007; Terpstra and Gutteling, 2008; Botzen *et al.*, 2009a; Martens *et al.*, 2009), mail distributed questionnaires remain the most popular self-administered method (e.g., Siegrist *et al.*, 2006; Benight *et al.*, 2007; Zhai and Ikeda, 2008; Zaalberg *et al.*, 2009; Kellens *et al.*, 2011). Being cost effective and easy to use, mail questionnaires are appropriate to reach a broad group of respondents. On-line questionnaires on the other hand are beneficial towards time budget and financial costs (no printing costs, less processing time of data) and allow the inclusion of more complex questions (e.g., questions that are only visible to certain groups). The administered method relies on interviews, either face-to-face or by telephone. Although these methods ensure high response rates, they are very labour-intensive and therefore generally less advantageous for surveying large samples. Nonetheless, some researchers have obtained samples over 500 respondents using computer-aided telephone survey software (CATI) such as VOXCO (Kreibich *et al.*, 2009). A minority of the studies (Krasovskaia, 2001; Terpstra *et al.*, 2006; Burningham *et al.*, 2008; Harries, 2008; Terpstra *et al.*, 2009; Lara *et al.*, 2010) have used focus groups. This method is particularly interesting for retrieving qualitative responses.

The third column in Table 4-1 depicts the number of respondents or sample size per study between brackets, next to the delivery method. In case more than one delivery method is used, the sample size is indicated per method, unless no information is provided in the study. Twelve studies had less than 100 respondents, 14 studies had sample sizes of 101 to 400, and as much as 30 studies had more than 400 respondents. One study (Raaijmakers *et al.*, 2008) failed to report the sample size. As Lindell and Perry (2000) indicate, studies with $N > 400$ have excellent power to produce significant results which are also representative for the total population. The correct sample size depends on the desired confidence level, the degree of reliability, and the degree of validity (Knocke and Kolivras, 2007). However, larger sample size invoke lower confidence limits, so a trade-off needs to be made between precision (reproducibility) and accuracy (closeness to the real value) (Alreck *et al.*, 2004).

4.6 Analysis methods

In this section, distinction is made between quantitative and qualitative analysis methods. Whereas quantitative studies are based on numerical data and statistical analyses, qualitative research uses verbal data and analyse this through conceptualization (Saunders *et al.*, 2006). However, it is sometimes difficult to distinguish both techniques. For example, some studies (e.g., McEwen *et al.*, 2002; Lopez-Marrero, 2010) have (partly) gathered information in a qualitative manner (e.g., trough open questions), but then have processed these data in a quantitative way. These doubtful cases were indicated with both QL (qualitative) and QN (quantitative) in Table 4-1.

Hereafter, the most frequently used quantitative and qualitative techniques in flood risk perception research are discussed. While the majority of the studies in flood risk perception have employed quantitative techniques, several qualitative methods are also worth mentioning.

4.6.1 Qualitative methods

Frequently used qualitative techniques are content analysis, discourse analysis and cognitive mapping. Content analysis is defined as a systematic, replicable technique for compressing many words of text into fewer content categories based on explicit rules of coding (Krippendorf, 2004). Several studies (e.g., Correia *et al.*, 1998; Knocke and Kolivras, 2007; Wagner, 2007) have employed this technique to simplify and structure large amounts of qualitative data to meaningful information. Discourse analysis is a general term for every type of analysis involving verbal information. When narrowly defined, it signifies the transcription and discussion of complete conversations or part of conversations. Burningham *et al.* (2008) and Harries (2008) have used this technique to discuss about the concerns and preferences of respondents regarding local flood risk. Whereas content and discourse analysis are restricted to verbal descriptions, cognitive mapping adds a visual or spatial component to a person's explanation. Moreover, the measurement of cognitive factors is also deemed an important factor in risk perception (Douglas, 1992). Ruin *et al.* (2007) employed cognitive mapping as a way to assess motorists' flash flood risk perception on their daily itineraries. Geographic information systems were consequently used to visualize the qualitative data onto a map. Ruin proposes to call these maps 'perception maps'.

4.6.2 Quantitative methods

Regarding quantitative research, it is clear that a multitude of statistical methods have been employed in the domain of flood risk perception, such as bivariate tests, tests of difference for two sample designs (e.g., t-test, Mann-Whitney), (multivariate) analyses of (co)variance (ANOVA, ANCOVA and MANOVA), (multiple) regression and factor analyses. Although most studies employ one or more of these tests, some are restricted to descriptive analyses of quantitative data (e.g., Devilliers and Maharaj, 1994; Wong *et al.*, 2001; Ali, 2007; Lara *et al.*, 2010).

As for bivariate analyses, typical correlation coefficients are Pearson (interval data), Spearman (ordinal data) and Chi-square (nominal data). Whereas some authors only mention 'intercorrelations' without further information, others (e.g., Ho *et al.*, 2008; Terpstra and Gutteling, 2008) state the type of coefficient that is used. Spearman's coefficient is most often applied since it allows comparing ordinal variables, such as various risk perception aspects. Tests of difference for two sample designs are also frequently used in risk perception research. Siegrist and Gutscher (2008), for example, employed the independent t-test, Kreibich *et al.* (2007; 2009) and Thieken *et al.* (2006; 2007) used the nonparametric Mann-Whitney test.

A large number of studies employed (multiple) regression models to clarify the relationship between a dependent or criterion variable (e.g., risk perception) and a set of independent or predictor variables (e.g., Griffin *et al.*, 2008; Miceli *et al.*, 2008; Zaalberg *et al.*, 2009; 2010; Kellens *et al.*, 2011). The advantage of applying multiple regression instead of several bivariate correlations (between the criterion variable and each of the predictor variables) is that multiple regression corrects for the correlations among the predictor variables (Brace *et al.*, 2006). Some studies applied analysis of variance (e.g., Benight *et al.*, 2007; Pagneux *et al.*, 2011), analysis of covariance (Keller *et al.*, 2006) or multivariate analysis of variance (Terpstra *et al.*, 2009), which are all specific analyses of the general approach adopted in multiple regression. A less frequently used alternative to multiple regression is logistic regression (Grothmann and Reusswig, 2006), in which the criterion variable is dichotomous. This approach implies a simple and straightforward way of measuring risk perception. Burningham *et al.* (2008), for example, assessed risk perception by asking the respondent whether he or she was aware of living in a flood-prone area (answer was yes or no). Other regression analyses that have been employed are fuzzy regression (Hung, 2009), Tobit regression (Zhai and Ikeda, 2006) and hedonic regression (Zhang *et al.*, 2010). A more sophisticated form of regression is Structural Equation Modelling (SEM), which has been performed in four studies (Zhai *et al.*, 2006; Zhai and Ikeda, 2008; Zaalberg *et al.*, 2009; Terpstra, 2011). This method combines multiple regression analysis with factor analysis and connects both by specifying non-measured latent variables. The possibility to include multiple dependent variables and the inclusion of measurement errors makes SEM advantageous to others.

4.7 Theories and empirical findings

In this section, an overview is presented of the theories that have been employed in flood risk perception research and the most important empirical findings that have resulted from them. Main distinction is made between studies that examined how people perceive flood risks (cf. Section 4.7.1) and studies that focused on people's behaviour in response to their exposure to flood risk (cf. Section 4.7.2). The few empirical studies that examined flood risk communication are discussed in Section 4.7.3. This section ends with an overview of important variables that have not been included in formal theories or tested as such (Section 4.7.4).

4.7.1 Examining risk perceptions

Psychometric Paradigm

An influential and popular theoretical framework in risk perception research is the Psychometric Paradigm. This theory, introduced by Fischhoff *et al.* (1978) and Slovic (1987), attempts to quantify individual's risk perceptions and attitudes through survey questionnaires. It further assumes that many characteristics of risk perception and their interrelationships can be quantified and modeled. In the questionnaires respondents are asked to express their perceptions on rating scales (expressed preferences) about various characteristics of the risk (e.g., severity and long-term consequences), their personal ability to cope with the risk (e.g., controllability, knowledge), their feelings (e.g., dread), and their attitudes toward risk management (e.g., trust). The quantitative ratings allow comparisons between risks (e.g., natural vs. technological hazards), but also between specific groups in the society (e.g., ethnic groups) and between countries (Boholm, 1998).

Applications of the Psychometric Paradigm indicate that flood risk is perceived differently between countries. For instance, mean ratings among a sample of Chinese lay people (Ge *et al.*, 2010) indicated that flood risk is perceived as an involuntary, uncontrollable, potentially fatal and catastrophic risk that evokes high levels of dread, but which is also seen as an 'old' risk, fairly known to both scientist and exposed citizens. In contrast, studies from the Netherlands (Terpstra *et al.*, 2006; Terpstra *et al.*, 2009) indicate that Dutch citizens are rather fearless with regard to flood risks, although the Dutch generally believe the risk is increasing due to global warming. One factor that is important for explaining such differences is the extent to which people are exposed to floods (e.g., due to differences in public flood protection and personal experiences). Lin *et al.* (2008) found that Taiwanese flood victims, compared to non-victims, perceived more dread, larger flood likelihood and consequences, and less personal control. However, victims and non-victims did not differ in their trust in the government's, experts' and the mass media's capabilities to respond flood crises (see also Ho *et al.*,2008) who reported on the same data). In addition to exposure, differences between countries may be explained by cultural differences or differences in social norms and values between societies. Ge *et al.* (2010) compared risk ratings from Chinese lay people to ratings of American citizens which were previously reported by Slovic (1987). Although the ratings from the two studies were quite similar for some risks (e.g., nuclear power were in both countries perceived as the number one risk), a comparison on floods could not be made since Slovic's study did not include flood risks (which was perceived as the second highest risk among the Chinese lay people). Yet, such comparisons are much needed in order to gain insight in the role of culture in risk perceptions. Ideally, they should be made within a single study to assure uniformity in the survey methodology and to avoid large time gaps between the surveys (the time gap between Slovic's and Ge's studies was more than 20 years, which makes direct comparisons between risks ratings questionable).

Heuristics

Another influential line of research is known as 'heuristics'. Heuristics, or simple and efficient rules of thumb, are often used by people to simplify complex problems and to make decisions without using all of their cognitive capacities. Although heuristics can be very helpful in daily life, research has shown that the heuristics are sometimes prone to systematic biases caused by a number of psychological phenomena. Well-known are the availability heuristic, the representativeness heuristic, and the anchor and adjustment heuristic (Tversky and Kahnemann, 1974). A fourth heuristic that is gaining increasingly more attention in flood risk research is the affect heuristic (Slovic *et al.*, 2004), which is closely connected with the risk-as-feelings hypothesis (Miceli *et al.*, 2008). Keller *et al.* (2006) pointed to this heuristic by testing the effect of affect-laden imagery on respondents. The results of their experiments suggested that affect (e.g., fear) is important for successful risk communication. Other researchers, such as Siegrist and Gutscher (2008), Miceli *et al.* (2008) and Terpstra (2011), have also acknowledged the significance of affect in perceiving and communicating flood risks.

Non-theoretical approaches to risk perception

Although both the Psychometric Paradigm and the heuristics approaches are influential methods in risk perception research, it seems that the majority of the studies which focus on flood risk perception does not employ them. The main reason for this finding lies in the explorative nature of most of these studies, which is reflected in the many risk perception characteristics that have been measured. However, the differences in measurement also suggests there exists no consensus on the type of questions or items that are needed to measure the various aspects of risk perception. As Miceli *et al.* (2008)

indicate, flood risk perception is a complex process that encompasses both cognitive (e.g., likelihood, knowledge, etc.) and affective (e.g., feelings, perceived control, etc.) aspects. Therefore, most studies employ (a different set of) multiple questions or items to measure the various aspects of risk perception. In order to process the items, different methods are applied. Most researchers (e.g., Heitz *et al.*, 2009) preserve the items as separate variables, but other authors like Miceli *et al.* (2008) or Kellens *et al.* (2011), respectively use the Partial Credit Model (PCM) and factor analysis to transform several items into one score. However, in some studies, perceived levels of flood risk have been measured by only one question or item. Examples are given in Burningham *et al.* (2008) and Horney *et al.* (2010).

To structure the measurement of risk perception, Table 4-1 classifies five different and frequently used variables or items within non-theoretical perception research[6]: items related to (i) awareness (or consciousness; e.g., 'Are you aware that you live in a flood-prone area?'), (ii) affect (or worry, fear, concern; e.g., 'Do you feel personally endangered by a flood?'), (iii) likelihood (or probability; e.g., 'What do you think about the chances of a flood in your neighbourhood within the next 10 years?'), (iv) impact (or consequences, vulnerability, e.g.,; 'Rate following statement: A flood will have fatal consequences for me and my family.') and (v) cause (or origin; e.g., 'Can you indicate the cause of the flood risk in your neighbourhood?'). The items of impact and likelihood are most often employed (respectively in 23 and 18 studies), followed by awareness (14 studies), affect (11 studies) and cause (8 studies). The frequent application of impact and likelihood is not startling given that flood risk is usually defined by the product of the probability that a flood hazard (likelihood) occurs with its consequences (impact). Most studies thus focus on both aspects in their measurement of flood risk perception.

4.7.2 Examining behaviour

Lindell and Perry (2004) distinguished three major categories of people's behaviour in the context of environmental hazards: (i) mitigation, (ii) preparedness and (iii) recovery. The three phases each occur at a different time relative to the actual flood event, or more in general, at different times

[6] In the case of theoretically supported research, the original items for risk perception are displayed in the table.

during the consecutive hazard phases, also known as the hazard life cycle or safety chain (FEMA, 2003; ten Brinke *et al.*, 2008). Mitigation measures are defined as those measures that have been taken in the past. Because these measures do not require action during impact, Lindell and Perry (2004) classified them as 'passive protection measures' (e.g., raisings one's home above the flood level). Preparedness measures on the other hand are last-call safety measures actions that are implemented shortly before or during impact ('active protection measures' such as placing sand bags, moving furniture to upper floors, evacuation, etc.). Recovery measures support people in returning to a normal state and in recovering their equilibrium. Flood insurance is such a recovery measure, because it helps people to deal with the financial consequences of floods.

In Table 4-1, main distinction is made between mitigation and preparedness. Attention is further given to studies that focus on insurance, information seeking and evacuation. Not surprisingly, the broader classes mitigation behaviour (26 studies) and preparedness behaviour (18 studies) are more often reported on than the more specific behaviours such as flood insurance (14 studies), information seeking (7 studies), evacuation (4 studies) and non-protective responses (4 studies). A further classification analysis is imperative, but will not be made here. Instead, we will shift our focus to the theories and variables that have been applied to predict people's behaviour in general. Distinction is made between the so-called Expectancy Valence theories (e.g., Protection Motivation Theory), applications of the contingent valuation method and qualitative approaches. The section ends with a brief overview of studies that have examined the above-mentioned behaviours but that have not employed a formal theory.

Expectancy Valence approaches

In the field of environmental hazards researchers have tried to explain people's adaptive behaviours most often by applying Expectancy Valence (EV) models. EV models are rooted in Vroom's (1964) expectancy theory, which proposes that people's behaviour can be predicted from their valences for different outcomes (e.g., desire to protect oneself against a perceived flood risk), the instrumentalities of their performance of actions leading to those outcomes (e.g., installing flood barriers), and expectancies about the relationship between their effort and successful performance (e.g., expected flood risk reduction). Various more specific theoretical models dealing with how people adapt to environmental hazards have adopted the propositions of EV theory. In our flood risk database these theories include the Protection Motivation Theory (PMT), the Protective Action Decision Model (PADM; Lindell and Perry, 2000; Lindell and Perry, 2004), the Motivation Intention Volition Model (MIV; Martens *et al.*, 2009) and the Risk Information Seeking and Processing model (RISP; Griffin *et al.*, 1999).

Both Grothmann and Reusswig (2006) and Zaalberg *et al.* (2009) have applied the Protection Motivation Theory to flood risks. Central to PMT are two processes: threat appraisal and coping appraisal. While threat appraisal refers to one's risk perception, coping appraisal expresses a person's perceived ability to cope with and avert being harmed by a threat. PMT defines three constructs that predict coping appraisals, namely response efficacy (the extent to which something is perceived as effective for reducing a threat), self-efficacy (the level of confidence in one's ability to undertake the recommended preventive behaviour), and response costs (assumed cost of taking the preventive behaviour). The theory further considers the influence of non-protective responses, such as denial, fatalism and wishful thinking. Grothmann and Reusswig (2006) found that both threat and coping appraisal determined people's adoption of flood hazard adjustments in the past (e.g., construction of structural measures, purchase of protection devices, etc.). Zaalberg *et al.* (2009) took these results one step further by looking at the individual contributions of perceived vulnerability, severity, response- and self-efficacy. While they found significant effects of response-efficacy on behavioural intentions, their measure of self-efficacy did not predict behavioural intentions. This is remarkable because reviews of PMT in other domains (primarily health) have indicated that self-efficacy is one of the strongest predictors of people's intentions and adaptive behaviour (Norman *et al.*, 2005). A possible explanation lies in the difficult operationalization of self-efficacy, which has been previously reported by Weinstein (1993). He observed that in PMT-studies measures of self-efficacy often question 'the problems individuals expect to encounter in adopting the precaution or doubts about their ability to change current patterns of behaviour', which refer more to the barriers or costs to do something (response costs) than to one's self-efficacy.

The Protective Action Decision Model (PADM; Lindell and Perry, 2000; Lindell and Perry, 2004) is closely related to PMT and has especially been applied to earthquake hazards. PADM has extended the concept of response-efficacy to three so-called efficacy attributes (perceived efficacy of hazard adjustments to protect to people, to protect property, and their utility for other situations). In addition, the efficacy attributes are distinguished from resource requirements (i.e., the extent to which adjustments are perceived to require money, time and effort, knowledge and skills, cooperation from other people, and specialized tools and equipment). Efficacy attributes are thus closely related to PMT's response efficacy, whereas the resource requirements are closely related to PMT's response costs. Studies conducted by Horney *et al.* (2010) and Lindell and Hwang (2008) were both inspired by the predictions of PADM but focused on perceived and actual flood risk rather than on the role of the efficacy attributes and resource requirements.

The Motivation-Intention-Volition model (MIV; Martens *et al.*, 2009) also relies on individual appraisals and proposes three phases that lead to adaptive behaviour. Motivation results from perceived risk but may be hampered by a lack of perceived personal responsibility and tendencies to avoid or suppress the perceived threat. A person's intention to adopt hazard adjustments is further influenced by perceived response and self-efficacy. Finally, in the volition phase intentions are turned into actions depending on the situational barriers that are encountered. Martens *et al.* (2009) employed latent class analysis to differentiate groups according to their motivation. Although their method appeared useful to provide information for targeting risk communications to specific groups, it had limited power to infer the constructs' contributions to the explained variance in people's adjustment decisions.

The Risk Information Seeking and Processing (RISP) framework, developed by Griffin *et al.* (1999), can be clearly distinguished from the previous theories since it deals specifically with information seeking and information processing tendencies (heuristic and systematic processing). The central concept of the model is a construct called 'information insufficiency', which is defined as the gap between a person's current knowledge and his/her knowledge threshold (i.e., whether his or her current knowledge is perceived as less than sufficient). Translated to the context of flood risks, Griffin *et al.* (2008) demonstrated that the desire for risk-related information and intentions for information seeking and processing was associated with anger at managing agencies, as well as with greater risk judgment of harm due to future flooding, greater sense of self-efficacy, lower institutional trust, and causal attributions for flood losses as being due to poor government management. Grothmann and Reusswig (2006) also examined information seeking behaviour in relation to coping appraisal, though they could not find a correlation between both constructs.

Applications of Contingent Valuation Methods

Rather than a formal psychological theory, CVM is an economical approach to elicit people's preferences for public goods, such as environmental quality or, in this case, flood protection. Specifically, CVM uses survey methods to analyse and explain people's willingness to pay (WTP), which is a monetary assessment of people's preferences.

Zhai pioneered in this study field by applying CVM to people's WTP for flood risk reduction and for avoiding evacuation inconveniences. A first study – by Zhai *et al.* (2006) – showed that people's WTP for flood risk measures may increase per capita income, individual preparedness, and/or experience with flooding, but may decrease with distance from a river, acceptability of flood risk, and provision of environmental information. A second study – by Zhai and Ikeda (2006) – examined the relation between flood risk acceptability and the economic value of evacuation (measured by willingness to pay for avoiding evacuation inconvenience). Zhai and Ikeda (2006) found that both flood risk acceptability and homeownership were two major statistically significantly determinants of the WTP. The authors suggested that there is a tradeoff between the public WTP's for ex ante or ex post measures. Later work by Zhai and Ikeda (2008) analysed flood risk acceptability inspired by the Rational Action Paradigm. In particular, the authors argued that the acceptance of risks should be viewed within a multi-risk context. As such, they found that flood risk perception and acceptability is correlated with the perception of other risks (e.g., technological risks). Finally, Hung (2009) incorporated fuzzy set theory into contingent valuation analysis to examine people's attitude towards flood insurance purchasing under preference uncertainty. Hung found that the perceived level of flood risk, experience with flood, disposable income, as well as house conditions and trust in the government are influential factors in the decision-making process for insurance purchase.

Qualitative approaches

Whereas standard communication models such as the normative theory (cf. Section 4.2.2) focus on the communication in two directions, some authors have suggested qualitative approaches that focus entirely on the receiver of the risk information, its risk knowledge, its preferences (cf. non-protective responses), and its information seeking behaviour.

A promising qualitative method is the mental models approach, which is widely applied in cognitive psychology (Weyma, 2003). In short, a mental model reflects a person's thought process about his/her observations in the real world. These thought processes are most often identified through qualitative face-to-face interviews. The mental models approach allows the identification of the public's knowledge schemes that are related to the risk, so that the content of the risk communication can be tailored to this knowledge (Visschers *et al.*, 2007). Assessing what the intended audience already knows or believes about a particular issue is important in designing effective risk communication messages (Bier, 2001). The mental models approach has been employed in Lave and Lave (1991) and Wagner (2007). Both studies showed that mental models are useful instruments to obtain qualitative information about flood risk perceptions to improve risk communication. Among a number of other conclusions, Lave and Lave (1991) mainly found that people know little about flood mitigation and preparedness. They acknowledged the importance of informing individuals about what they can do to make their houses flood-proof. Wagner (2007) found that local conditions have a major effect on people's knowledge. Those who use many different sources to inform themselves, express fear about natural hazards, or have previous experience with hazards, generally have a better knowledge about the particular hazard.

The usefulness of qualitative research is also demonstrated by Harries (2008), who applied the Social Representations Theory to explain why some individuals are more willing than others to take self-protective actions against flood risks. The approach revealed that people who are at risk will be more susceptible to risk mitigation if they are able to relinquish their feeling of security, which is determined by representations of home, nature and society.

Non-theoretical findings on adaptive behaviour

A number of studies have examined people's behaviour towards flood risks without the use of a formal theory.

Using a probit regression analysis, Botzen *et al.* (2009b), for example, found that higher perceived flood probability increased citizens' intentions of purchasing sand bags. Miceli *et al.* (2008) obtained similar results by employing correlational and regression analyses. In contrast to these findings, Brilly and Polic (2005) reported that flood concern was not significantly correlated with the preparedness to conduct preventive measures. Instead, they found that place of residence had a strong influence on preparedness intentions. Other researchers have measured and utilized adjustment behaviour mainly to pose policy recommendations. Kreibich *et al.* (2009), for example, measured people's mitigation behaviour in the context of groundwater flooding in Germany. Based on the very low number of precautionary measures taken by the respondents, they suggested intensifying communication about this specific type of flooding. McEwen *et al.* (2002) from his side pled for the implementation of adjustments to ensure that sustainable development of caravan parks is possible. Wong (2001) described functional adjustment approaches in rural China to combat flood hazards. Although people are reported to getting accustomed to frequent floods, Wong revealed a public demand for financial reserves by the government so that people can invest in hazard-resisting houses.

Regarding evacuation intentions, Horney *et al.* (2010) found that residents with a medium or high flood risk perception more often evacuated if they lived in an apartment or mobile home instead of a stick-built home instead. This pattern could not be observed for respondents with low risk perceptions. Other researchers, such as Krasovskaia (2001) and Ologunorisa and Adeyemo (2005), measured evacuation intentions, but did not test correlations with other variables.

A number of studies have examined people's attitude and intentions towards insurance purchasing. While in some countries (e.g., Belgium), flood insurance is mandatory (e.g., as part of a fire insurance policy), other countries leave it to the residents' decision whether or not to buy a flood insurance. However, it might be difficult for people to make such decision towards a low-probability, high-loss event (Hung, 2009). Factors that have been related to flood insurance adoption are homeownership (Takao *et al.*, 2004), income (McEwen *et al.*, 2002) and flood exposure (Figueiredo *et al.*, 2009). Thieken *et al.* (2006) found that insured people – compared to uninsured people – exhibit higher intentions to carry out precautionary measures, such as collecting information, participating in networks and adapting building use and interior equipment. In the aftermath of a large flood event, insured people showed slightly less intentions to invest in further mitigation in the future. Overall, however, Thieken *et al.* (2006) warns for alarming behaviour since about one-third of the interviewed households who were affected by the flood, neither purchased insurance nor invested in loss mitigation. Finally, several researchers examined insurance attitude descriptively, without specific significance-tests or analyses on correlations (e.g., Devilliers and Maharaj, 1994; Lin *et al.*, 2008; Olcina Cantos *et al.*, 2010).

Noteworthy are two studies that examined people's risk-seeking behaviour in relation to flood risk perception. Benight *et al.* (2007) linked risk behaviour of motorists driving through an intersection with 6" of moving water to the experience of flood-related traumas. Botzen *et al.* (2009a) applied a risk-seeking index on financial risks to the willingness of people to purchase flood insurance.

4.7.3 Examining risk communication

Among our selection of studies, only two have explicitly focused on flood risk communication. The first study is Griffin and colleagues' (2008) attempt to describe the public's risk communication activity in the context of flood hazards, using the Risk Information Seeking and Processing (RISP) framework (a detailed discussion on their findings has been given in Section 4.7.2). A second study has examined the impact of flood risk communication on the perceptions and attitudes of the public. By means of a quasi-experimental study, Terpstra *et al.* (2009) evaluated the effects of a small-scale flood risk communication program in the Netherlands, consisting of workshops and focus-groups. Two mechanisms of attitude change – direct personal experience and attitude polarization – were measured among the participants of the workshop and the focus group and were subsequently evaluated in a pretest-posttest control group. In contrast to what was expected, risk communication had only weak effects on the participant's risk perception. In search for an explanation of these findings, the authors addressed a number of issues, which should be considered in further research, such as refined scales, homogeneous participant samples and a closer correspondence between information conditions and risk perception measures (Terpstra *et al.*, 2009).

While very few authors have explicitly addressed flood risk communication in their research, many studies have made recommendations toward risk communication, such as preferred flood probability formats, perceived uncertainty and information preferences. Keller *et al.* (2006), for example, examined the effect of the flood probability format on risk perception and found that participants who received risk information concerning a longer time period (e.g., 30 years) perceived more danger compared with participants who received risk information for one year. Bell and Tobin (2007) went further into this matter and measured the effects of four descriptive flood uncertainties in a flood-prone community: a 100-year flood, a flood with a 1 percent chance of occurring in any year, a flood with a 26 percent change of occurring in 30 years and a flood risk map. They found that the 1 percent description was more effective in conveying uncertainty than the 100-year description, but less effective in motivating attitudes of concern or protection. Finally, Kreibich *et al.* (2009) measured the respondent's preferences for types of information dissemination channels regarding groundwater flooding. According to their findings, means of information should be preferably radio, television, newspapers and the internet.

4.7.4 Other important variables

A number of variables that have been reported are not incorporated in any theory, or at least have not been tested as such. Among these are empirical results related to (i) knowledge, trust and protection responsibility, (ii) physical exposure and hazard experience, and (iii) socio-demographics.

Knowledge, trust and protection responsibility

Hazard knowledge refers to someone's knowledge about a hazard's genesis, its mechanisms of exposure, and types of hazard adjustments that can avoid its impacts (Lindell and Perry, 2004). While hazard knowledge is inextricable bound up with approaches such as the RISP model (Griffin *et al.*, 1999) and the mental models approach (Lave and Lave, 1991; Wagner, 2007) (cf. Section 4.7.2), it has been found a difficult construct to quantify (cf. Griffin *et al.*, 2008). Most studies therefore operationalize hazard knowledge as perceived knowledge, by asking respondents to what extent they think or believe their knowledge reaches about risk-related topics. As such, perceived hazard knowledge is generally found strongly linked to perceived vulnerability or feeling of security (Lopez-Marrero, 2010). Botzen *et al.* (2009a) quantified hazard knowledge by asking respondents about the causes of a flood. They found that individuals with little knowledge of the causes of floods have lower perceptions of flood risk. This outcome is supported by Raaijmakers *et al.* (2008) who state that provision of flood risk information to the public usually increases their awareness or perception. Ruin *et al.* (2007) operationalized knowledge in yet another way, namely by employing cognitive mapping to understand people's decisions regarding flood risks.

When people lack knowledge about a hazard, their risk judgments are based on the degree to which they trust the responsible risk managers. As such, knowledge is conceptually related to trust. The construct of trust has been studied in the context of the Psychometric Paradigm (Terpstra *et al.*, 2006), affect heuristics (Terpstra, 2011), PMT (Grothmann and Reusswig, 2006) and RISP (Griffin *et al.*, 1999). Trust may refer to institutional trust (e.g., in the government's abilities to cope with a flood hazard) or trust in specific flood protection measures (e.g., the resistance of a seawall). Terpstra (2011) noted that trust and affect share similarities, since both constructs reduce the complexity of risk judging and consequently serve as a 'quick' guide to assess risks. Both Terpstra (2011) and Hung (2009) found that trust in public flood protection was negatively related to preparedness and insurance purchases intentions, respectively, and Grothmann and Reusswig (2006) reported that relying on flood protection was negatively correlated with the adoption of flood mitigation measures in the past and information seeking. In contrast, reports by Lin *et al.* (2008) indicated that higher levels of trust or confidence in crisis management and provision of flood warnings (by government, risk experts, and media), increased mitigation intentions, insurance purchase intentions and information seeking intentions. These contradicting findings seem hard to explain. It should be noted, however, that the three former studies (Grothmann and Reusswig, 2006; Hung, 2009; Terpstra, 2011) focused on the extent to which people trust in public flood protection (i.e., flood defences), whereas the latter study (Lin *et al.*, 2008) focused on the provision of flood warnings in a crisis situation.

Perceived protection responsibility reflects the degree to which a person perceives personally responsible for taking individual protection measures against a hazard. This construct has been addressed mostly in the domain of earthquake hazard (Lindell and Perry, 2000). Empirical evidence has shown that adaptive behaviour is more likely when people perceive protection as their personal responsibility. In the context of flood risks, most studies confirmed this relationship. For instance, Lara *et al.* (2010) found that personal responsibility is positively correlated with mitigating actions such as moving furniture to upper floors and information seeking. However, reports by Terpstra and Gutteling (2008) suggest that the correlations of protection responsibility may differ between protective actions. Although a lower damage responsibility was correlated with less favourable attitudes towards private damage mitigation actions, the correlation with disaster preparedness attitude was not significant. Moreover, correlations of protection responsibility with behavioural intentions were non-significant, both for taking damage mitigation actions and emergency preparedness actions.

Physical exposure and previous experiences

To date, effects of physical exposure to flood hazards and experiences with previous flood events have been hardly theorized. Nevertheless, numerous studies have shown that both variables can have effects on risk perception and efficacy beliefs or hazard adjustments.

The physical exposure to a flood hazard is mostly determined by the resident's location, which is related to the visibility of and the distance or proximity to the hazard source (e.g., a river, the sea, etc.). Positive correlations between flood hazard proximity and risk perception have been found by Heitz *et al.* (2009) and Lindell and Hwang (2008). From their findings, it seems that people who reside farther away from flood hazard sources (such as coastlines, rivers, etc.) exhibit lower levels of perceived risk. Lindell and Hwang (2008) tested whether this outcome is caused by a lack of hazard experience, but they could only find partial rather than complete effects. Some authors reported that proximity of one's home to a river or coastline increases behavioural intentions of taking mitigation and preparedness measures. Botzen *et al.* (2009b), for example, reported a marginally significant effect of proximity on willingness to buy sand bags. Others have employed hazard proximity and risk perception to predict other variables. Zhang *et al.* (2010), for example, found that flood risk perception is a significant mediating factor between hazard proximity and property value.

Previous hazard experiences were generally found to increase risk perceptions (e.g., Keller *et al.*, 2006; Siegrist and Gutscher, 2006; Knocke and Kolivras, 2007; Krasovskaia *et al.*, 2007; Burningham *et al.*, 2008; Ho *et al.*, 2008; Miceli *et al.*, 2008; Lara *et al.*, 2010; Kellens *et al.*, 2011) and the likelihood that people adopt hazard adjustments (e.g., Grothmann and Reusswig, 2006; Thieken *et al.*, 2006; Siegrist and Gutscher, 2008; Hung, 2009). Pagneux *et al.* (2011) found that people with flood experience had more knowledge and better understanding of historical floods. Results by Zhai and Ikeda (2006) indicated that evacuations can cause inconveniences such as shortages of information and food. Such inconveniences were regarded as an important factor for causing low rates of evacuation in Japan. Several authors (e.g., Halpern-Felsher *et al.*, 2001; Lindell and Perry, 2004) suggested that the effect of experience depends on how people interpret their experiences or what they have learned from them. Factors that shape risk perceptions are the magnitude of the effect, the risk target, and the frequency and recency of experiences. While it is reasonable to assume that large-scale flood hazards will have a greater impact than a local flood (Wilson, 1990), the concept of risk target might need a word of explanation. The risk target indicates whether the respondent is personally affected by the hazard (personal experience) or not (community or vicarious experience) (Peacock *et al.*, 2005). Botzen *et al.* (2009a), for example, reported that citizens with previous flood and evacuation experience expressed higher perceived flood likelihood but lower perceived flood consequences, presumably because hardly any of the respondents with flood experience had actually suffered personal flood damage. Finally, Siegrist and Gutscher (2006) have shown that more recent and frequent floods lead to higher levels of risk perception depending on the magnitude and the (personal) damage occurred. Burn (1999) summarizes the effect of experience by stating that 'prior experience with flood events appear to be most useful when it is recent and relevant to the current event'.

Several studies have suggested that the effects of experience on perceived risk and behaviour are rather indirect than direct, and are thus mediated by other variables. Lindell and Hwang (2008) found that perceived personal flood risk completely mediated the effect of hazard experience on flood mitigation behaviour (e.g., raising electrical components above flood level), but risk perception only partly mediated the effect of experience on flood insurance purchase. It was suggested that the partial mediation effect was found because other unmeasured variables may also mediate effects of experience. Extensive mediation analyses by Zaalberg *et al.* (2009) indicated that Dutch flood victims as compared to non-victims had stronger coping intentions because they perceived themselves as more vulnerable to future floods, which in turn resulted from experiencing stronger negative emotions (e.g., fear) caused by their previous flood experiences. Interviews in Switzerland also pointed to the idea that fear for future flood damages is a more important determinant of precautionary behaviour for victims than for non-victims (Siegrist and Gutscher, 2008). Their analyses indicated that victims compared to non-victims expressed stronger negative (e.g., fear) and positive emotions (e.g., sociability) as a result of their flood experiences, received more social support from family, friends (etc.), worried more about future flooding, perceived themselves as more vulnerable and perceived the consequences of future flooding as more severe. Flood victims also perceived higher response efficacy and had stronger intentions to take adaptive actions (e.g., moving furniture upstairs) than non-victims, but did not differ from non-victims in their perceived response efficacy of preventive actions (e.g., putting sand bags in front of the house) and their intentions to take these actions. Terpstra (2011) reported that emotions attached to previous flood hazard experiences failed to have significant, direct effects on flood preparedness intentions among Dutch citizens. Mediation analyses indicated that although emotions influenced preparedness intentions indirectly, the mediations paths differed between sample locations. The author argued that the discrepancy might be explained by the severity of the disaster consequences combined with the time at which the emotions were assessed. In particular, Terpstra (2011) investigated emotions two months after a heavy storm, about fifteen years after mild river floods, and fifty-five years after a severe flood disaster. Because these emotions become less salient as time goes by, the impact of these emotions on risk perceptions and adaptive behaviours fade away too.

Socio-demographics

Socio-demographic characteristics are examined in almost every study on flood risk perception. While most studies measure these characteristics primarily to describe the sample and demonstrate its representativeness (Knocke and Kolivras, 2007), significant – but often small – correlations are regularly found with risk perception (Griffin *et al.*, 2004). The most important characteristics seem to be age, gender, education, income and home ownership. Age is generally found to be positively correlated with flood risk perception (Lindell and Hwang, 2008; Kellens *et al.*, 2011), although negative outcomes have also been found (Botzen *et al.*, 2009a). As for gender, several studies (e.g., Ho *et al.*, 2008; Lindell and Hwang, 2008) found that men have on average lower perceived levels of flood risks than women. However, Botzen *et al.* (2009a) discovered the opposite relation. Regarding education, lower educated people usually show higher levels of risk perception (Armas and Avram, 2009). Ho *et al.* (2008) refines this relation by considering the controllability of the flood risk. They suggest that people with more years of education may obtain and understand new information more easily. As a result, they may be aware of more mitigation actions from local governments and experts, and may feel a higher degree of controllability over a disaster. Often related to the educational level is income, since people with a superior educational level have, on average, larger incomes (Armas and Avram, 2009). Lopez–Marerro and Yarnal (2010) also recognize a positive correlation between income and housing conditions (construction materials) and housing location, as people with lower incomes will predominantly reside in poorer housing conditions in less favourable areas (e.g., flood-prone areas). In general, income is negatively correlated to risk perception (Lindell and Hwang, 2008; Zhang *et al.*, 2010), though statistical significance is often absent (Ho *et al.*, 2008; Botzen *et al.*, 2009a). Finally, home ownership has also been related to perceived risks. Several studies (e.g., Burningham *et al.*, 2008; Kreibich *et al.*, 2009) suggests that owning a property results in higher levels of perceived risk than renting a residence. Grothmann and Reusswig (2006) explain that home owners may suffer much more losses than tenants, since a great deal of flood damage occurs to the building itself.

4.8 Discussion

This chapter presented an overview of the state of the art in the research on perception and communication of flood risks, including 57 studies from 22 different countries. Two aspects stand out in this review. First is the diversity of approaches including the use of theories, measurement instruments and data analytic procedures. The study field is still very young and subsequently attracts many researchers from many different study domains. Researchers bring along different approaches, constructs and methods, which explains why similar goals are assessed in different ways (cf. Boholm, 1998). Second is the almost complete absence of true risk communication research. In this final section we discuss these issues and propose a research agenda for the near future.

4.8.1 Theoretical and methodological issues

Many theories were used to predict people's risk perceptions (psychometric paradigm, heuristics) and their adaptive behaviours (e.g., PMT, PADM, CVM). Qualitative approaches were also used to map out people's mental models of flood risks. Application of well-established theoretical frameworks seems necessary to propose sound hypotheses (i.e., theoretically justified) that can be tested empirically using smart research designs, validated measurement instruments, and sophisticated data analyses. Ultimately, this will lead to theoretical progression and result in a more complete understanding of people's flood risk perception and their (non-)adaptive behaviours. So far, however, the majority of studies (i.e., 60%) refrained from using theories. As a result, approaches and methods within the field are often very heterogeneous, which makes results from different studies difficult to compare. This might be one of the main reasons why some findings don't seem to confirm each other or even be inconsistent to each other. For example, many studies presented their own regression models for the prediction of risk perceptions, attitudes (e.g., towards government relief) or intentions (e.g., buying flood insurance). Although significant predictors were mostly found in these models, explained variances were often relatively low, indicating noise or the presence of other, non-measured confounding variables. While it is impossible to cancel out noise, it is a challenge to improve measurement instruments. We suggest three steps to tackle this issue. First, authors can improve their measurement instruments by carefully considering the theoretical constructs that are needed to measure/predict flood risk perceptions and adaptive behaviours. Second, the operationalization of theoretical constructs can be ameliorated by copying or at least by reflecting on previously reported questionnaire items. Third, authors should report about the reliability of their measures, as well as their means, standard deviations and their correlations. In particular, Structural Equation Modelling (SEM) can be used to explicitly identify the presence of noise (unreliability) in measurement instruments.

Another point that needs more attention is the analysis of mediation and causality. For instance, three studies tested the extent to which the effects of flood experience on adaptive behaviour were mediated by flood risk perceptions (Lindell and Hwang, 2008; Zaalberg *et al.*, 2009; Terpstra, 2011) In other words, flood experiences were expected to stimulate adaptive behaviour because experiences influence people's risk perceptions and their perceptions of flood hazard adjustments, which in turn influence their adaptive behaviours. Performing mediation analyses is important for understanding the relations between variables, which is indispensible for advancing theories. In addition, the word 'because' suggests that one was able to establish causality – for instance, that perceived risk causes adaptive behaviour and not the other way around (cf. Weinstein and Nicolich, 1993). This is important since many studies have assumed causal relations to predict risk perceptions and/or behaviour, but provided evidence based on cross-sectional research designs. Although it is tempting to report on causality, cross-sectional surveys cannot provide sufficient evidence to do so (Lindell and Hwang, 2008). To test causal relations, (quasi) experimental and longitudinal research designs are needed in addition to the cross-sectional surveys (Lindell and Perry, 2000). Although it has been argued that it is difficult to simulate flood experiences with severe financial losses in experiments, effects of direct (personal) flood experiences and indirect (vicarious) experiences produced by social communications can be measured in longitudinal surveys (Siegrist and Gutscher, 2008; Terpstra, 2011).

4.8.2 Communication issues

It is now widely acknowledged that risk communication can strengthen people's risk awareness and motivate those at risk to take preventive actions and be prepared for an emergency case (Hagemeier-Klose and Wagner, 2009). It is further accepted that the knowledge of the public's risk perception is an important factor in building effective risk communication strategies (Basic, 2009). However, it is apparent that only a few studies take the plunge to define recommendations for flood risk communication. Moreover, most of these recommendations are indefinite, and the focus or objective of the risk message often differs from situation to situation. Knocke and Kolivras (2007), for example, emphasized the need to elaborate educational programs on flash flood risks. These programs could be accomplished through training sessions, presentations at public functions, informational fliers, etc., which focus on understanding the flood causes and possible consequences, increasing awareness of warning sources, and informing the public about available tools and data. Instead of raising awareness and understanding, Kreibich *et al.* (2009) stated that communication should primarily concentrate on the necessity of individual preparedness. Bell and Tobin (2007) suggested that more extensive use of qualitative methods would also help in the practical interpretation of statistical relationships. Finally, Martens *et al.* (2009) pled for more attention to the heterogeneity of the public. It is not sufficient to simply provide the same message to all individuals at risk because they will perceive this information differently and will subsequently respond in different ways. Although all these recommendations undoubtedly have important value in risk communication, it is difficult to put them into practice.

In fact, empirical research on the effects of flood risk communication is still very limited. In a quasi-experimental design, Terpstra *et al.* (2009) tested the impact of a small-scale flood risk communication program in the Netherlands. In contrast to what was expected, risk messages had weak to no effect on people's risk perception and attitude polarization. Yet, their study has cleared the way for more research in this context.

There is also very limited theoretical background with regard to flood risk communication. Griffin *et al.* (2008) have applied their RISP model in the context of flood hazards, but many questions remain regarding the cognitive and affective processes that play a role in people's information seeking behaviour.

4.8.3 Future research agenda

This review chapter has shown that the study field has undergone a remarkable growth during the last years. Studies from around the world have been conducted and empirical evidence is being gathered in an increasing pace. Nevertheless, as the previous sections have indicated, there is room for further research in the field.

First of all, future research should strive for more theoretical support and more methodological 'openness'. There exist a wide range of theories which may fulfil the needs of wide range of objectives. Whether the focus is on a strict analysis of people's risk perception, whether it is the intention to assess people's attitude toward preparedness measures, whether it is the aim to affect people's behaviour, etc., it is always possible to rely on existing theories, models or frameworks. Profound empirical testing of previous theories may lead to new insights and model improvements, on condition that the selection and measurement of constructs is 'open' and well-grounded. After all, it can be problematic if studies do not report the contents of the items employed, since it precludes other scholars to verify how constructs were measured or results were obtained.

With regard to theoretical extensions and variations, future research could work towards a framework which puts more emphasis on the effects of physical exposure and hazard experience. Although both constructs have been examined quite often, they have been hardly theorized (Burningham *et al.*, 2008; Lindell and Hwang, 2008; Zhang *et al.*, 2010). Future studies in risk perception could further attempt to employ experimental and longitudinal designs more often, in order to enable causality inference.

It has been shown that research on the determinants and the effects of flood risk communication is in its early stages. Future research should address the relation between flood risk perception and flood risk communication more thoroughly. It is apparent that many perception studies refer to risk communication in their 'further research' (Siegrist and Gutscher, 2006; Ge *et al.*, 2010; Zhang *et al.*, 2010), but very few link both (Bell and Tobin, 2007; Kreibich *et al.*, 2009). More research should be conducted on people's information preferences (Lindell and Hwang, 2008), on the effects of risk information on people's behaviour (Terpstra *et al.*, 2009) and on fostering private adaptation (Grothmann and Reusswig, 2006). Stemming from the latter, future research should also look at various cost-effective mitigation measures and how these can be implemented in traditional flood risk management (Botzen *et al.*, 2009b).

In sum, there is still considerable work to do. Inspired by Botzen *et al.* (2009a), we can say that research on flood risk perception and communication is still in its infancy. Although both research domains have gone a long way in the past decades, there is need for more definition, clearer methods, and more comparability.

Appendix

The table below presents the selection of articles reviewed in this chapter.

Table 4-1 Overview of peer-reviewed empirical studies in flood risk perception research

Author, Year	**Study area Flood type**	**Survey method (N) Analysis (methods)**	**Theory**	**Flood risk perception variables**	**Behavioural variables**	**Physical Exposure Variables & Demographics**	**Other important variables**
Ali, 2007	Bangladesh River flood	FI (453) QN (Descriptive)	-	Cause	Mitigation, Preparedness	Experience, Risk area, Demographics	-
Armas & Avram, 2009	Romania (Danube Delta) River flood	FI (153) QN (Correlation, ANOVA, Cluster, Factor)	-	Affect, Impact	-	Risk area, Demographics	Locus of control
Arthur et al, 2009	UK (Edinburgh) Sewage flood, Other hazard	FI (173) QN (Descriptive)	-	Impact, Cause	-	Experience, Demographics	Potential improvement of wastewater treatment works, Sewage service provider's performance
Bell & Tobin, 2007	USA (Texas, Wimberly) Flash flood	FI (45) QN (Factor, t-test, Wilcoxon)	-	Affect	-	Risk area	Perceived flood uncertainty, Map accuracy, Need for flood protection, Information preferences
Benight *et al.*, 2007	USA (Colorado/Texas) Flash flood	MQ (342) QN (ANOVA)	-	Awareness, Affect, Impact	Risk behaviour	Experience, Risk area	-
Botzen *et al.*, 2009a	The Netherlands River flood	OQ (982) QN (Ordered probit, Binary probit, OLS)	-	Likelihood, Impact, Cause	Risk behaviour	Experience, Distance from river, Elevation relative to water level	-
Botzen *et al.*, 2009b	The Netherlands River flood	OQ (509) QN (Probit)	-	Likelihood, Impact	Mitigation, Preparedness, Insurance	Experience, Distance from river, Elevation relative to water level, Dike protection	Responsibility, Climate change perceptions
Brilly & Polic, 2005	Slovenia (Celje) River flood	FI (157+208) QN (Multiple regression, Cluster)	-	Awareness, Likelihood, Impact, Affect	Preparedness, Insurance	Experience, Risk area	Warning / Forecast attitudes
Burningham *et al.*, 2008	UK (England/Wales) River flood	FG, FI (934) QL (Discourse analysis), QN (Logistic regression)	-	Awareness	-	Experience, Risk area, Length of time at present address, Demographics	Provision of flood warning service

Author, Year	**Study area Flood type**	**Survey method (N) Analysis (methods)**	**Theory**	**Flood risk perception variables**	**Behavioural variables**	**Physical Exposure Variables & Demographics**	**Other important variables**
Correia *et al.*, 1998	Portugal (Setubal) Flash flood	FI (101) QL (Content analysis)	-	Likelihood, Cause	Mitigation, Preparedness	Experience, Residential history	Public participation
De Villiers & Maharaj, 1994	South Africa (Durban) River flood	Q (n.s.) (60) QN (Descriptive)	-	Likelihood, Cause	Mitigation, Insurance	Experience, Distance from river	Costs of mitigation, Protection responsibility
Figueiredo *et al.*, 2009	Portugal (Agueda) River flood	FI, MQ (823) QN (Descriptive)	-	Cause	Mitigation, Insurance	Experience, Risk area,	Protection responsibility, Awareness of public flood protection
Ge *et al.*, 2010	China (Yangtze River Delta) River flood, Other hazards	MQ (275) QL, QN (Descriptive)	Psycho-metric Paradigm	Voluntariness, Immediacy, Known to exposed / science, Controllability, Newness, Catastrophic potential, Dread, Severity of consequences	-	-	Risk ranking
Griffin *et al.*, 2008	USA (Milwaukee) River flood	TI (401) QN (Regression)	Risk Information Seeking and Processing	Institutional trust, Personal efficacy, Risk judgment	Information seeking	Experience, Demographics	Information insufficiency, Perceived information gathering capacity, Channel beliefs, Informational subjective norms, Information processing
Grothmann & Reusswig, 2006	Germany (Cologne) River flood	TI (157) QN (Logistic regression)	Protection Motivation Theory	Perceived probability, Perceived severity, Fear	Mitigation, Preparedness, Information seeking, Non-protective responses	Experience	Coping appraisal, Trust in flood protection
Harries, 2008	United Kingdom Flood (n.s.)	FI, FG (40) QL (Discourse analysis)	Social Re-presen-tations Theory	-	Non-protective responses	-	Representational barriers (home, society, nature)
Heitz *et al.*, 2006	France (Alsace) Muddy flood	MQ (34) QL, QN (Descriptive)	-	Awareness, Impact	-	Risk area	Importance of muddy flood risk relative to other risks, Risk management, Institutional trust

Author, Year	Study area Flood type	Survey method (N) Analysis (methods)	Theory	Flood risk perception variables	Behavioural variables	Physical Exposure Variables & Demographics	Other important variables
Ho *et al.*, 2008	Taiwan Flood (n.s.), Other hazard	TI (2559) QN (Correlation, Factor, ANOVA, Multiple regression)	Psycho-metric Paradigm	Likelihood, Affect, Impact, Controllability, Knowledge of private mitigation actions	-	Experience, Demographics	Riskiness of various hazards
Horney *et al.*, 2010	USA (North Carolina) Coastal flood	FI (570) QN (Bivariate, multivariate)	Protective Action Decision Model	Impact	Evacuation	Hurricane experience, Type of home, Risk area, Home location	Social cohesion
Hung, 2009	Taiwan (Keelung River basin) River flood	FI (405) QN (Fuzzy regression)	Fuzzy Contingent Valuation	Likelihood	Insurance	Experience, Distance from river, Risk area, Demographics	Preference uncertainty, Property insurance, Insurance attitude, Cost, Trust (information, public protection)
Kellens *et al.*, 2011	Belgium Coastal flood	MQ (619) QN (Correlation, Multiple regression)	-	Likelihood, Affect, Impact	-	Experience, Risk area, Permanent residence, Demographics	-
Keller *et al.*, 2006	Switzerland Flood (n.s.)	Three Experiments; FI (170, 92), MQ (1598) QN (ANOVA, Tukey, ANCOVA)	Affect and Availability Heuristics	Likelihood, Impact	-	Experience	Flood probability formats
Knocke & Kolivras, 2007	USA (Virginia) Flash flood	OQ (300) QL (Content analysis), QN (Chi-square)	-	Awareness, Likelihood, Impact		Experience, Risk area, Length of residency	Verbal descriptions of flash floods / adverse impacts, Information preferences
Krasovskaia, 2001	Norway (Glomma catchment) River flood	FG (24), TI (900) QL, QN (Descriptive)	-	Likelihood, Impact	Evacuation	Experience	Perceptions about flood protection
Krasovskaia *et al.*, 2007	Germany, Netherlands, Norway, Sweden UK Floods (n.s.)	TI (3996) QN (Descriptive)	-	Awareness, Likelihood, Affect	Mitigation	Experience	Information sufficiency, Protection responsibility

Author, Year	Study area Flood type	Survey method (N) Analysis (methods)	Theory	Flood risk perception variables	Behavioural variables	Physical Exposure Variables & Demographics	Other important variables
Kreibich *et al.*, 2007	Germany (Saxony) River flood	TI (415) QN (Mann-Whitney, Kruskal-Wallis)	-	Awareness, Likelihood	Mitigation, Preparedness, Insurance	Experience (including warning response), Length of time at the location	Efficacy of previous mitigation / preparedness actions; Time / costs / help required for taking preparedness actions
Kreibich *et al.*, 2009	Germany (Dresden) Groundwater flood, Flood (n.s.)	TI (605) QN (Mann-Whitney, Kruskal-Wallis, Principal Components)	-	Affect	Mitigation, Preparedness	Experience	Protection responsibility, Information preferences
Lara *et al.*, 2010	Spain (Costa Brava) Flood (n.s.)	FI (285), FG (26) QN (Descriptive)	-	Impact, Cause	-	Experience, Temporary versus permanent residents	Public participation
Lave & Lave, 1991	USA (Pennsylvania) River / Flash flood	FI (22) QL (Content analysis)	Mental model	Awareness, Cause	Insurance	Experience	Protection responsibility, Cost-benefits insurance, Attitudes towards government relief, Knowledge of mitigation actions
Lin *et al.*, 2008	Taiwan Flood (n.s.), Other hazards	TI (1340) QN (Factor, Multiple regression)	Psycho-metric Paradigm	Likelihood, Dread, Control, Severity of consequences, Knowledge of mitigation actions	Mitigation, Insurance	Experience	Trust in risk management and communication sources, Vulnerability
Lindell & Hwang, 2008	USA (Texas) Flood (n.s.), Other hazards	MQ(321) QN (Multiple regression)	Protective Action Decision Model	Perceived personal risk	Mitigation	Experience, Tenure expectations, Distance from risk source, Demographics	-
Lopez-Marrero, 2010	Puerto Rico (Fajardo River valley) River flood	FI (36) QL (Content analysis)	-	Likelihood, Impact	Mitigation, Preparedness	Experience	Response efficacy, Cost, Time / Effort, Knowledge / skill requirements, Help from others, Physical health, Social networks, Trust in flood protection

Author, Year	**Study area Flood type**	**Survey method (N) Analysis (methods)**	**Theory**	**Flood risk perception variables**	**Behavioural variables**	**Physical Exposure Variables & Demographics**	**Other important variables**
Lopez-Marrero & Yarnal, 2010	Puerto Rico (Fajardo River valley) River flood; Other hazards	FI (56) QL, QN (Participatory ranking)	-	Affect, Likelihood, Impact	-	Risk area	Concerns of various risks with their perceived importance / severity
Martens *et al.*, 2009	Germany (Bremen) Flood (n.s.)	TI (589), OQ (242) QL, QN (Latent class analysis)	Motivation Intention Volition Model	Impact	Mitigation, Preparedness	-	Protection responsibility, Social vulnerability
McEwen *et al.*, 2002	UK (Midlands) River flood	FI (58), MQ (16) QL, QN (Descriptive)	-	Awareness	Mitigation, Insurance	Experience	Warning perceptions and response
Miceli *et al.*, 2008	Italy (Aosta Valley) Flood (n.s.)	TI (407) QN (Factor, Correlation, Regression)	Risk-as-feelings	Impact, Affect	Mitigation, Preparedness	Experience, Distance from nearest water course, Demographics	-
Olcina Cantos *et al.*, 2010	Spain (Alicante) Flood (n.s.)	Q (n.s.) (85) QN (Descriptive)	-	Awareness, Impact	Mitigation, Insurance	Experience, Risk area, Permanent versus seasonal residents	Public risk management attitude
Ologunorisa & Adeyemo, 2005	Nigeria (Niger Delta) River flood	Q (n.s.) (432) QN (Descriptive)	-	Likelihood, Impact, Cause	Mitigation, Evacuation	Experience	-
Pagneux *et al.*, 2011	Iceland Flash flood	FI (112) QN (ANOVA, Correlation)	-	Awareness, Affect, Likelihood, Impact	-	Experience, Risk area, Length of residence	-
Raaijmakers *et al.*, 2008	Spain (Ebro Delta) Coastal flood	FI (-) QN (Descriptive)	Psycho-metric Paradigm	Awareness, Affect	Mitigation	-	-
Ruin *et al.*, 2007	France (Gard) Flash flood	FI (200) QL (Cognitive mapping), QN (Correlation)	-	Awareness, Impact	-	Experience, Travel behaviour, Length of residence	Knowledge about protective actions, Sources of information
Siegrist & Gutscher, 2006	Switzerland Flood (n.s.)	MQ (1213) QN (Multiple regression)	-	Impact	Mitigation	Experience, Risk area	Insurance attitude

Author, Year	**Study area Flood type**	**Survey method (N) Analysis (methods)**	**Theory**	**Flood risk perception variables**	**Behavioural variables**	**Physical Exposure Variables & Demographics**	**Other important variables**
Siegrist & Gutscher, 2008	Switzerland Flood (n.s.)	FI (201) QN (t-test, Chi-square)	Affect heuristic	Affect	Mitigation, Preparedness	Experience	Response efficacy, Costs, Time / knowledge requirements
Takao *et al.*, 2004	Japan (Nagoya City) Flood (n.s.)	MQ (2051) QN (Chi-square)	-	Likelihood, Affect	Mitigation, Insurance	Experience	-
Terpstra, 2011	The Netherlands	OQ (472, 428, 861)	Affect heuristic	Likelihood, Impact, Affect	Preparedness	Experience, Demographics	Trust
Terpstra *et al.*, 2006	The Netherlands River / Coastal flood	MQ (49), FG (14) QN (Factor, Correlation)	Psycho-metric Paradigm	Increasing risk, Dread, Knowledge, Controllability, Number of people exposed, Risk-benefits, Trust	-	-	State / Trait Anxiety
Terpstra & Gutteling, 2008	The Netherlands (Friesland) Coastal flood	OQ (658) QN (Correlation)	-	Likelihood, Affect, Impact	Mitigation, Preparedness	Demographics	Protection responsibility, Trust in flood protection
Terpstra *et al.*, 2009	The Netherlands Coastal flood	Quasi-experimental; MQ, FG (80) QN (MANOVA, Chi-square)	Psycho-metric Paradigm, Persuasive Arguments Theory	Increasing risk, Dread, Known to Science / Exposed, Controllability, Trust, Public support	-	Demographics	-
Thieken *et al.*, 2006	Germany (Elbe catchment) River flood	TI (1248) QN (Mann-Whitney)	-	Awareness, Likelihood, Impact	Mitigation, Preparedness, Insurance, Information seeking	Experience	Mitigation response efficacy, Time spent on preparedness, Participation in emergency network
Thieken *et al.*, 2007	Germany (Saxony, Saxony-Anhalt and Bavaria) River / Flash flood	TI (1697) QN (Mann-Whitney, Kruskal-Wallis, Correlation)	-	Awareness, Likelihood, Impact	Mitigation, Preparedness, Insurance	Experience, Risk Area, Perceived quality of the building	Mitigation response efficacy, Warning / Response questions
Wagner, 2007	Germany (Bavarian Alps) Flash flood, Other Hazard	FI (169), TI (1205) QL (Content analysis), QN (t-test, ANOVA, Correlation)	Mental Model	Awareness, Affect, Cause	Non-protective response	Experience, Demographics	Risk management attitudes

Author, Year	**Study area Flood type**	**Survey method (N) Analysis (methods)**	**Theory**	**Flood risk perception variables**	**Behavioural variables**	**Physical Exposure Variables & Demographics**	**Other important variables**
Wong & Zhao, 2001	China (Beijing River catchment) River flood	FI (52) QN (Descriptive)	-	Awareness, Impact	Mitigation	Experience	Trust in flood risk management, Responsibility
Zaalberg *et al.*, 2009	The Netherlands River flood	MQ (516) QN (Structural Equation Modelling)	Protection Motivation Theory	Affect, Likelihood, Impact	Mitigation, Preparedness, Non-protective responses	Experience, Demographics	Self efficacy, Response efficacy, Social support
Zhai & Ikeda, 2006	Japan (Sanjyo, Fukui and Toyo'oka) Flood (n.s.)	MQ (1259) QN (Tobit regression)	Contingent Valuation Method	Flood risk acceptability	Evacuation	Experience, Risk Area, Demographics	Evacuation inconvenience
Zhai *et al.*, 2006	Japan (Toki-Shonai River basin) River flood	MQ (428) QN (Regression; Covariance structure analysis)	Contingent Valuation Method	Likelihood, Impact	Preparedness	Experience, Risk Area, Distance from river, Demographics	Preferences for public flood control, Flood risk acceptability, Perception of other risks, Information provision
Zhai & Ikeda, 2008	Japan (Toki-Shonai River basin) River flood	MQ (428) QN (Correlation, Covariance structure analysis)	Rational Action Paradigm	Likelihood, Impact	Preparedness, Insurance	Experience, Risk Area, Distance from river, Demographics	Flood risk acceptability, Perception of other risks, Information provision
Zhang *et al.*, 2010	USA (Texas) Coastal flood, Other Hazard	MQ (321) QN (Correlation, Hedonic regression)	-	Impact	-	Hazard proximity, Demographics	Housing price

MQ = mail questionnaire, OQ = on-line questionnaire, FG = focus group, FI = face-to-face interview, TI = telephone interview
QL = qualitative analysis, QN = quantitative analysis
n.s. = not specified
All studies performed cross-sectional surveys unless stated otherwise.

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5 AN ANALYSIS OF THE PUBLIC PERCEPTION OF FLOOD RISK ON THE BELGIAN COAST

Modified from: *Kellens, W., Zaalberg, R., Neutens, T., Vanneuville, W., De Maeyer, P., 2011. An analysis of the public perception of flood risk on the Belgian coast. Risk Analysis, 31, pp. 1055-1068.*

Abstract

In recent years, perception of flood risks has become an important topic to policy makers concerned with risk management and safety issues. Knowledge of the public risk perception is considered a crucial aspect in modern flood risk management as it steers the development of effective and efficient flood mitigation strategies. This chapter aims at gaining insight into the perception of flood risks along the Belgian coast. Given the importance of the tourism industry on the Belgian coast, this study considered both inhabitants and residential tourists. Based on actual expert's risk assessments, a high and a low risk area were selected for the study. Risk perception was assessed on the basis of scaled items regarding storm surges and coastal flood risks. In addition, various personal and residence characteristics were measured. Using multiple regression analysis, risk perception was found to be primarily influenced by actual flood risk estimates, age, gender and experience with previous flood hazards.

5.1 Introduction

5.1.1 Background

Flood hazards are worldwide considered as one of the most significant natural disasters in terms of human impact and economic losses (Jonkman, 2005). A specific type of flood hazards comprises coastal floods caused by storm surges. Storm surges imply a set-up of the sea level at coastal areas and are generally induced by strong winds and low atmospheric pressure (Jonkman and Vrijling, 2008). Examples of such storm surges are hurricanes, cyclones and typhoons. Recent disasters, such as hurricane Katrina in New Orleans (2005) and cyclone Sidr in Bangladesh (2007) have shown the catastrophic potential of coastal floods.

In Belgium, the most recent severe coastal flood occurred in 1953. Then, one of the largest storm surges of the last centuries struck the coastal areas surrounding the North Sea, leading to severe floods in Belgium, the Netherlands and United Kingdom. Because the time of the storm surge peak coincided with the time of spring-tide high water, the total water level reached heights that, in many locations, exceeded those recorded ever before. The resulting disaster was enormous in terms of loss of life and damage to infrastructure (Baxter, 2005; Gerritsen, 2005). In the years ensuing, an important part of the Belgian seawalls was reinforced (Charlier and Demeyer, 1992). These hard defence structures characterize the Belgian coast and nowadays constitute pleasant promenades for coast-dwellers. For several years, however, no new seawalls have been built. Instead, soft techniques such as beach feeding have been applied frequently. At present, nourishments are the main technical measures preventing the Belgian coast from a new disaster (Mertens *et al.*, 2008). In addition to these measures, numerous technological advances have been made in weather forecasting, risk mitigation procedures, emergency planning, etc. (McRobie *et al.*, 2005).

Both coastal defence investments and technological advances may have brought the public to a false sense of safety regarding flood hazards. Moreover, the rareness of events such as floods may allow social awareness of extreme and unsafe situations to fade (Colten and Sumpter, 2009). Due awareness of coastal flood risks remains however indispensable. In a Belgian context, two important developments underline this need. The first development is the global climate change. Climate models of the Intergovernmental Panel on Climate Change (IPCC) predict a global sea level rise of 0.3 to 0.6 meter during the 21st century, leading to a higher vulnerability of coastal areas around the world (Nicholls *et al.*, 2007). Focusing on the Belgian coast, Lebbe *et al.* (2008) have achieved similar findings. They state that, despite the natural and artificial defence structures, an increased vulnerability of the Belgian coastal plain is expected due to sea level rise. The second development is the growing economic importance of the Belgian coast. Approximately 0.4 million people (4% of the Belgian population) live in the flood-prone area. During the summer period, this number increases by approximately 0.3 million residential tourists. The growing economic significance of the Belgian coast is a result of the flourishing beach tourism, the agriculture in the low-lying polder areas and a variety of fishing and harbour activities (Allaert, 1996).

As a consequence of the climate-change induced sea level rise and the continuing economic growth in the coastal area, parts of the Belgian coast are considered to be vulnerable to coastal floods, not only with regard to material vulnerability (tangible damage) but also human vulnerability (intangible damage). One of the major Flemish projects devoted to this issue is the Integrated Master Plan for Flanders Future Coastal Safety, led by the Agency for Maritime and Coastal Services. The main objective of this project (2007-2011) is to prepare the Belgian coast for storm surges, considering climate change impacts until 2050 (Mertens *et al.*, 2008). A similar project, CLIMAR, seeks for wide-ranging solutions regarding coastal defence structures on the Belgian coast (Van der Biest, 2008). While these projects have extensively studied quantitative risk assessments, the public perception and opinion remain highly underexplored. Understanding people's risk perception and its determining factors is however crucial for improving risk communications and effective mitigation policies (Ho *et al.*, 2008; Heitz *et al.*, 2009). The knowledge about risk perceptions of natural hazards may further provide important information about people's willingness to take precautionary measures, and the public support for governments' risk reduction policies (Botzen *et al.*, 2009). While risk perception studies have largely focused on inhabitants, far less attention has been given to the perception of tourist populations. Nonetheless, Burby and Wagner (1996) have underlined the vulnerability of tourists towards local hazards, because tourists are less independent and less familiar with local hazards and the resources that can be relied on to avoid risk.

By means of a questionnaire survey, this chapter seeks to probe into the perception of inhabitants and residential tourists towards storm surges and flood risks along the Belgian coast. Using multiple regression analysis, insight is gained into how various personal, experiential and residence characteristics contribute to the level of risk perception. Attention is also paid to the correspondence of the perceived risk with the expert's risk assessment in high and low risk areas.

The remainder of this section gives a brief overview of literature related to the role of risk perception in flood risk management and to research regarding public perception versus expert's risk assessment. Based on available evidence in previous studies, research aims and hypotheses are formulated. Subsequently, research site selection, survey method and sample characteristics are described in Section 5.3. Section 0 presents the results of the multiple regression analysis. The chapter ends with a discussion and outlines the avenues for further research in the field of flood risk perception.

5.1.2 Risk perception and flood risk management

The study of risk perception involves the examination of people's awareness, emotions and behaviour with regard to hazards. While originated in the nuclear debate of the 1960s (Sowby, 1965; Starr, 1969), risk perception has become more and more prevalent in numerous other areas. One of these areas is flood risk management which comprises the comprehensive task of considering all natural and societal processes related to flood hazards (Messner and Meyer, 2006). According to its conventional definition, risk is deemed a quantifiable variable and is analysed on the basis of probabilities and consequences (Raaijmakers *et al.*, 2008). While risk analysis methods generally rely on aspects of objective risk measures, subjective risk measurement such as risk perception is currently being recognized as an essential aspect in the context of flood risk management (Schanze, 2007). The knowledge of people's perception level allows researchers to identify qualitative risk characteristics (e.g., 'voluntary', 'immediate', 'known to exposed', 'known to science', 'not controllable', etc.) and compare risks associated with different hazards (Slovic, 1987). Furthermore, the knowledge of risk perception is promoted as prerequisite to achieve effective risk communication (Keller *et al.*, 2006). Terpstra *et al.* (2006), for example, indicate that limited knowledge about risk perception of flood hazards may lead to difficulties in communicating these risks and, moreover, in unsatisfactory knowledge about risk reducing measures. Without thorough perception research, risk communication may suffer from limited understanding of the interests, concerns, fears, values, priorities, and preferences of individual citizens and public groups (Bier, 2001).

5.1.3 Expert versus public in risk perception

While experts have generally used statistical data to estimate and compare risks, the risk judgment of the public relies largely on qualitative factors, such as seriousness of the consequences, sense of control, and recency and (perceived) frequency of the hazard (Jacobs and Worthley, 1999). The discrepancy between the expert's risk assessment and the public's risk perception is often demonstrated in literature (Wright *et al.*, 2002). Burningham *et al.* (2008), for example, reported difficulties in interpreting the meaning of a 'one in a 50 year' flood: an older respondent answered she did not have to worry because she was already 75 years old. Another person in the study did not understand how a once in 50-year flood had occurred twice in five months. Some researchers, however, have refuted the statement that experts are more veridical in their risk assessments than members of the public. Rowe and Wright (2001), for example, have identified methodological weaknesses in a number of empirical studies, such as poorly defined characteristics of the expert and the lay samples, and the absence of information to determine expert's reliability. Results of Siegrist and Gutscher (2006) confirm these weaknesses. Their study showed little to no evidence of differences in flood risk perception between the public and the experts.

5.2 Research aims and hypotheses

Past research about hazard perceptions has sought to identify and quantify the different factors that might predict people's attitude towards risk (Chauvin *et al.*, 2007). In the context of flood risks, perception research has articulated the impact of personal experience with previous flood hazards and socio-demographic variables on perceived personal risk (e.g., Whitmarsh, 2008; Armas and Avram, 2009; Botzen *et al.*, 2009; Zaalberg *et al.*, 2009). While most of these studies have examined the public perception of flood hazards in general, only few have explicitly focused on the perception of coastal flood risks (Kaiser *et al.*, 2004). Furthermore, the ways in which residence characteristics (e.g., residing on ground floor) may affect flood risk perception has remained understudied in the context of flood risks (Kreibich *et al.*, 2005). Finally, from Section 5.1.3, it appears that there is also still no consensus with respect to the 'expert versus public' issue.

This chapter explicitly addresses these issues in a case study on the Belgian coast. Based on previous evidence from the literature, which is reviewed below, five hypotheses are formulated. The first three hypotheses concern the effect of expert's risk assessment (location), socio-demographic factors and residence characteristics on risk perception. Hypothesis 4 and 5 consider the mediating effect of hazard experience variables and the moderating effect of residing permanently on the Belgian coast for the relation between location and risk perception, respectively.

5.2.1 Expert's risk assessment (location)

In this study, the perception of inhabitants and residential tourists of flood risks is measured in three coastal municipalities on the Belgian coast: Oostende, Knokke-Heist and De Panne (with 69,000, 34,000 and 10,000 inhabitants, respectively). Figure 5-1 depicts the location of the studied municipalities, together with a summary of the present defence structures. The municipalities were selected because they exhibit diverse characteristics in terms of (i) the scientifically estimated flood risk, (ii) the presence of coastal defence structures and (iii) the impact of the storm surge of 1953. These characteristics will be discussed below.

In recent years, experts from Flanders Hydraulics Research (Belgium) have combined various hydraulic models with socio-economic data to produce damage and risk maps for both river and coastal flood scenarios (Vanneuville *et al.*, 2003). According to these risk assessments, Oostende is expected to have higher flood risks than De Panne and Knokke-Heist. Unlike the other municipalities, several parts of Oostende are located at an elevation below high tide sea level. The municipality of De Panne on the contrary is considered to have one of the safest beaches regarding flood risks. A combination of a wide beach – 450 meters at low tide – and a mean elevation above high tide sea level results in a relatively low coastal flood risk. According to estimates, the actual flood risk in Knokke-Heist is somewhat higher than in De Panne but considerably lower than in Oostende.

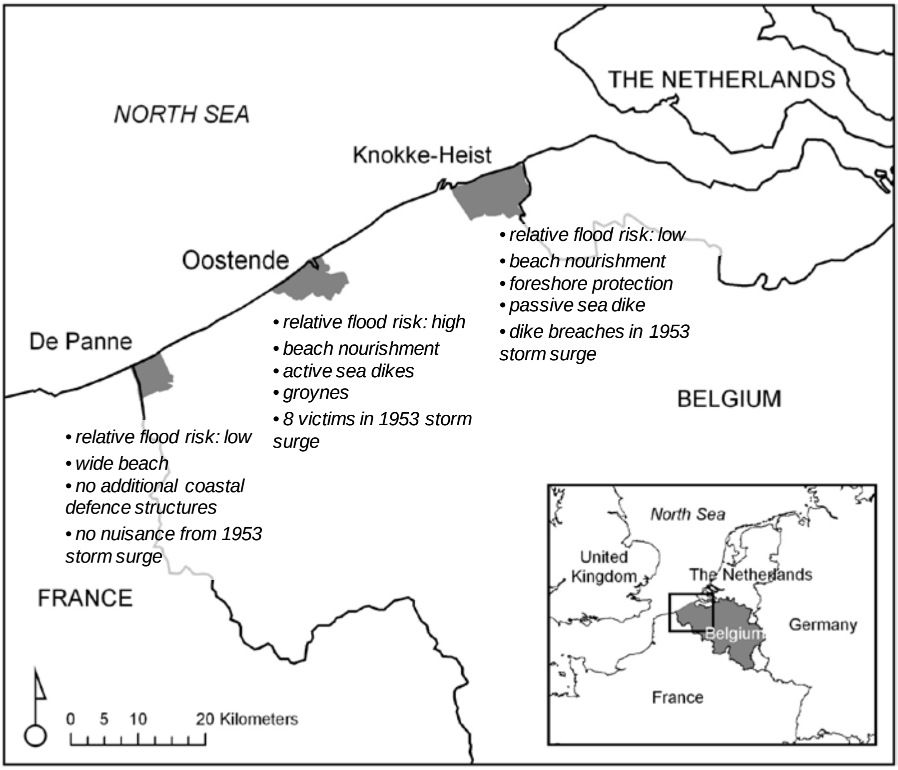

Figure 5-1 Location of the study area with a summary of the selection factors

The examined municipalities further differ in the presence of coastal defence structures. In Oostende, the most important defence structures are beach nourishment (artificial raising of the beach), an active sea dike and groynes. The town of Knokke-Heist is protected by beach nourishment, foreshore protection and a passive sea dike. In De Panne, no additional defence structures are applied. The wide beach makes extra defence efforts superfluous.

Finally, the 1953 storm surge had a quite different impact on the examined municipalities. In the city centre of Oostende, average water depths amounted to 93 cm. The inundation was primarily caused by the fishing port's dikes which were not high enough to compete against the water level. In total, eight people were killed in Oostende. In Knokke-Heist, coastal dikes were damaged and parts of the town flooded, though much less extensive than in Oostende. The municipality of De Panne experienced practically no nuisance from the severe storm (N.N., 2003).

Given the above characteristics regarding the expert's risk assessment, the coastal defence structures and the storm surge experience, a reasonable distinction can be made between a high risk area (Oostende) and a low risk area (Knokke-Heist and De Panne), leading to the first hypothesis:

H1: It is expected that respondents from Oostende (high expert's risk assessment) will exhibit higher levels of perceived risk than those from Knokke-Heist and De Panne (low expert's risk assessment).

5.2.2 Socio-demographic factors

Individual socio-demographic characteristics can play an important role in shaping risk perception of natural hazards (Peacock *et al.*, 2005; Chauvin *et al.*, 2007). For example, risk appears to be a gendered phenomenon: woman are more risk averse than men (Brody, 1984). Jonkman and Vrijling (2008) found that on average 70% of the casualties in flood hazards are male. They attribute this gender discrepancy to the high involvement of men in driving, the high proportion of men in the emergency and supporting services, and men's risk-taking behaviour. These findings may suggest that men have on average a lower risk perception than women. Also often associated with risk perception are the factors age and household composition. Age has been found to be positively correlated with risk perception of a number of natural hazards (Grothmann and Reusswig, 2006; Lindell and Hwang, 2008). Household composition is generally defined by the presence or number of children in het household. The literature is equivocal about the influence of this factor on risk perception. Houts *et al.* (1984), for example, have concluded that the presence of children is a primary indicator of a household's perceived susceptibility to a nuclear threat. Similar outcomes were reported regarding volcano risk perception (Perry and Lindell, 1990) and evacuation response (Drabek, 2001). In the domains of earthquake (Lindell and Prater, 2000) and hurricane risks (Peacock *et al.* 2005), however, presence of children did not have significant effects on perceived risk. Further, education can also be associated with risk perception. In the context of technological hazards, Savage (1993) found that lower educated people show higher levels of risk perception. Finally, home ownership has also been related to perceived risks. Past research on flood hazards (Grothmann and Reusswig, 2006; Burningham *et al.*, 2008) suggests that owning a property results in higher levels of perceived risk than renting a residence. Finally, it has been argued that staying permanently on a hazardous place may amplify risk perception (Lindell and Hwang, 2008).

The above findings provide a rationale for Hypothesis 2. Because of literature disagreement, the effects of presence of children are not hypothesized.

> H2: Coastal flood risk perception is expected to be positively related with age, female gender, lower education, home ownership, and permanent residence.

5.2.3 Residence characteristics

The characteristics of a person's residence can be determinant towards flood damage. It has been reasoned that people having a cellar or residing on the ground floor, are more vulnerable to flooding. Kreibich *et al.* (2005), for example, formulated a set of precautionary measures in which an elevated configuration and fortification of cellar and ground floor are advised for buildings in flood-prone areas. Siegrist and Gutscher (2008), on the other hand, mention that 20 to 36% of the people store valuable content in their cellars. In Belgium, cellars often contain the electricity closet and the heating system. The presence of water in the vicinity of these systems may result in power failure and damage to household appliances, computers, televisions and other electronic devices in the house or apartment building. Most cellars on the Belgian coast are situated below high tide sea level.

An additional residence characteristic deals with the visibility of the hazard from the residence location. This characteristic is closely related to hazard proximity. In past research, correlations between hazard proximity and perceived risk have been found for technical hazards such as chemical installations (Brody *et al.*, 2004) and for natural hazards such as earthquakes (Lindell and Perry, 2000), hurricanes (Arlikatti *et al.*, 2006) and floods (Miceli *et al.*, 2008). It seems that people who are farther away from hazard sources, exhibit lower levels of perceived risk (Lindell and Hwang, 2008). However, to date there is little consensus about about the effects of hazard visibility on risk perception. While some (e.g., Burningham *et al.*, 2008) have argued positive relations between visibility and perception of flood hazards, others (e.g., Colten and Sumpter, 2009) have argued that visible cues of rare hazard sources – such as floods – might cause a false sense of safety, resulting in lower levels of risk perception. Apart from this literature disagreement, we will go with the majority of research findings and hypothesize a positive relation between sea view and risk perception.

These arguments provide a rationale for Hypothesis 3:

> H3: Residing on the ground floor, or residing in a house with a cellar or sea view will be related to higher levels of coastal flood risk perception.

5.2.4 Location and hazard experience

Many researchers have stressed the importance of previous hazard experiences in people's judgments about risk (Barnett and Breakwell, 2001; Kreibich *et al.*, 2005; Grothmann and Reusswig, 2006). Distinction is often made between direct personal experience and vicarious experience. Direct personal experience can be defined by the recency and frequency of casualties and damage experienced by the respondent (Lindell and Hwang, 2008). Vicarious experience refers to social communication, i.e., hearing or reading about hazard impacts affecting friends, relatives or neighbours. Because attitudes based on direct experiences are more accessible in memory, direct personal experience has a greater potential to influence perceived personal risk (Terpstra *et al.*, 2009). Past research supports this thesis. In a multi-hazard environment, Lindell and Hwang (2008) found that people who have previously been exposed to a hazard were far more aware than people without hazard experience. Hazard experience may also be determined by location. People staying on locations exposed to higher risk values will have a greater chance of experiencing risk-related events, e.g., people staying on the coast have a greater chance of experiencing a hazardous storm surge than people living inland. This argumentation invokes a mediating relation between location and perceived personal risk via hazard experience.

Two types of hazards are considered in this study: floods and storm surges. Storm surges are defined as a set-up of the sea level at coastal areas, sometimes resulting in over-topping of sea water on dikes (Jonkman *et al.*, 2008). In the case of structural failing such as dike breaching, a storm surge can result in coastal flooding (cf. 1953 storm surge). Although the focus of this study is on the perception of coastal flood risks, experience with flood types occurring inland (e.g., river floods) is also taken into account because these might influence the perception of hazards in general (Green *et al.*, 1991). This is particularly relevant in our case study given that the survey also considers coastal tourists, who may have experience with flood types other than coastal floods or coastal storm surges.

Hypothesis 4 is stated as follows:

> H4: The effect of location on perceived personal risk is expected to be mediated by direct personal experience with storm surges and/or (coastal) floods.

5.2.5 Location and permanent residence

The factors location and permanent residence have been discussed before (see Hypothesis 1 and 2 respectively). However, it can be argued that both factors might interact. Assuming that residents usually have more belongings that can be damaged by a flood compared to (visiting) tourists, location will have a differential impact on risk perception for both categories of respondent type. To be more precise, residents living permanently in a high-risk place (Oostende) exhibit higher risk perception compared to residents living permanently in a low-risk place (Knokke-Heist and De Panne). Moreover, it is expected that location will not affect tourists' risk perception. This reasoning results in the fifth Hypothesis:

> H5: Location will impact risk perception for residents but not for tourists.

5.3 Methodology

5.3.1 Survey method

The survey method consists of a paper questionnaire, containing scaled items regarding storm surges and coastal flood risks. Based on questionnaires previously developed in the context of flood risk perception (Terpstra *et al.*, 2006), five items were selected and – if necessary – adapted for the present research (Table 5-1). All items were measured on a 5 point-scale ranging from no agreement at all (score: 1) to full agreement (score: 5), with a neutral opinion in between (score: 3). Cronbach's alpha of the five risk perception items is .80, indicating an adequate internal consistency. Principal factor analysis with varimax rotation was used to obtain just one component having an eigenvalue above 1 (explained variance 55.4%). Based on the factor loadings on this component, weighted factor scores are assigned to all observations. The resulted risk perception score follows a normal distribution $N(0,1)$ and ranges from -2.39 to 2.19. Higher values indicate stronger levels of risk perception and vice versa.

Table 5-1 Perception of flood risk: items

1	*I'm worried about the danger of a storm surge on the Belgian coast*
2	*A storm surge can have fatal consequences for the coastal area and its inhabitants*
3	*I experience staying on the Belgian coast as a threat to my safety*
4	*I expect great chances of storm surges causing floods in the coastal area*
5	*When I think of floods, I feel concerned*

Socio-demographic characteristics and information regarding hazard experience were assessed as follows. Age was measured as a continuous scale in years, gender was obtained as dichotomy (female = 1, male = 0). Home ownership, residing permanently on the Belgian coast, presence of children at home and direct personal experience with past storm surges and floods were all measured as dichotomy (yes = 1, no = 0), as well as education ('high education' (i.e., high school or university degree) = 1; 'low education' (i.e., primary or secondary school degree) = 0). Additionally, three residence characteristics were obtained: (i) having a cellar, (ii) living on the ground floor and (iii) staying in a residence with sea view (all three were measured as dichotomy: yes = 1, no = 0). Finally, location was coded as follows: Oostende (high expert risk assessment) = 0; Knokke-Heist/De Panne (low expert's risk assessment) = 1.

Given the current aim of evaluating risk perception at two locations along the Belgian coast, the survey is organized as a stratified sampling with proportional allocation. The size of the subsamples in each stratum (municipality) was chosen in proportion to the size of the stratum. The number of permanent inhabitants is used as size indicator for each stratum, leading to a partition of 60% for Oostende compared to 40% for Knokke-Heist and De Panne. Two different distribution methods were used. The first method involved distribution of questionnaires via systematic sampling in postboxes (5/6 of all questionnaires). In order to reach sufficient respondents having sea view, a number of streets were randomly selected in the vicinity of the shoreline. The second method consisted in personally handing over the questionnaires to inhabitants and residents in the streets of the three municipalities, thereby providing a brief word of explanation. It was hoped that this personal hand-over would result in a higher response rate.

5.3.2 Sample characteristics

Overall, 619 respondents (20.6%) answered the questionnaire. Table 5-2 lists the response rates per location (Oostende; Knokke-Heist and De Panne) for both personal hand-overs and postboxes. As was hoped, the personal hand-over method resulted in a considerably larger response rate than the postbox method (35.4% against 17.7% respectively). In general, response rates were somewhat better in Oostende than in Knokke-Heist and De Panne (22.5% to 17.8% respectively).

Table 5-2 Response numbers in each municipality according to distribution method (personal hand-over / via postboxes)

		Personal hand-over		**Postboxes**		**Total**	
		Number	%	Number	%	Number	%
Location	*Oostende*	96	32.0	309	20.6	405	22.5
	Knokke-Heist + De Panne	81	40.5	133	13.3	214	17.8
Total		177	35.4	442	17.7	619	20.6

Table 5-2 displays the overall frequencies of the personal characteristics. Respondent's age ranged from 17 to 88 years (M = 58.3, SD = 14.3). The majority of the sample (66 %) was male, which can be attributed to the fact that the questionnaire was addressed to the head of the family. The ratio between owners and non-owners of residences is about three to one. Approximately 70% of the sample resides permanently on the Belgian coast. These values closely mirror the actual situation, as measured by the research and consultancy office of West Flanders (WES) (Gunst *et al.*, 2008). The ratio between the number of people with a low educational level (i.e., degree of primary or secondary school) and a high educational level (i.e., high school or university degree) is about fifty-fifty. Roughly one fourth of the respondents has one or more children living at home.

The question as to whether or not the respondents had experience with previous storm surges resulted in remarkable outcomes. While half of the respondents reports to have witnessed a storm surge on the Belgian coast, less than one out of four participants answered affirmative to the question 'Have you ever experienced a flood in the past?' The smaller percentage of people having experienced floods compared to storm surge experience results from the fact that not every storm surge causes a flood. Noteworthy is that the storm surge of 1953 was mentioned quite often in an open question ('Can you indicate the year of the most severe storm surge you have experienced to date?'). In Oostende, 34 % of the respondents with storm surge experience refer to the one of 1953 against a minority (ca. 10 %) in the two other municipalities.

Three additional variables were questioned regarding the respondent's present residence on the coast: (i) having sea view or not, (ii) living on the ground floor or not and (iii) having a cellar or not. Table 5-3 indicates that roughly one-third of the respondents has sea view, one-third lives on the ground floor and one-third lacks a cellar.

Table 5-3 Sample statistics: frequency in numbers and percentage per variable

Variable	**#**	**%**	**Variable**	**#**	**%**	**Variable**	**#**	**%**
Age			*Education*			*Sea view*		
16-30	27	4.4	High	314	50.7	Yes	220	35.5
31-45	82	13.2	Low	299	48.3	No	385	62.2
46-60	219	35.4	Missing	6	1.0	Missing	14	2.3
61-75	221	35.7						
76-90	68	11.0	*Children living at home*			*Ground floor*		
Missing	2	0.3	Yes	167	27.0	Yes	185	29.9
			No	448	72.4	No	418	67.5
Gender			Missing	4	0.6	Missing	16	2.6
Male	409	66.1						
Female	209	33.8	*Storm surge experience*			*Cellar*		
Missing	1	0.1	Yes	303	48.9	Yes	386	62.3
			No	313	50.6	No	214	34.6
Home ownership			Missing	3	0.5	Missing	19	3.1
Owner	474	76.6						
Tenant	142	22.9	*Flood experience*					
Missing	3	0.5	Yes	139	22.5			
			No	477	77.1			
Permanent residence			Missing	3	0.4			
Yes	438	70.8						
No	181	29.2						
Missing	0	0.0						

5.4 Results

In this study, two analyses are conducted. First, a correlation analysis is performed to check for multicollinearity among predictor variables. A multiple regression analysis is consequently used to explore the predictive values of location, personal and residential characteristics, as well as hazard experience for perceived levels of coastal flood risks.

5.4.1 Correlation analysis

Table 5-4 depicts the correlations between all variables: personal characteristics (6), hazard experience (2), residential characteristics (3) and location (1).

Among the significant relevant correlations are those concerning the variables permanent residence, storm surge experience and location. A high positive correlation between permanent residence and storm surge experience shows that inhabitants more frequently observe storm surges than tourists. As for location, significant negative correlations were found with the variables permanent residence and storm surge experience, indicating that more respondents reside permanently in Oostende than in the other municipalities. The negative correlation between location and storm surge experience illustrates a higher storm surge experience in Oostende.

Most importantly, the analysis showed no correlations higher than 0.60 which is a strong indication for the absence of multicollinearity among the predictors.

Table 5-4 Correlations between variables

		Mean	N	1	2	3	4	5	6	7	8	9	10	11	12
1	*Age*	58.30 *(SD 14.263)*	617	-											
2	*Gender*	.34	618	-.174**	-										
3	*Home ownership*	.77	616	.165**	-.008	-									
4	*Permanent residence*	.71	619	.068	.044	.205**	-								
5	*Education*	.51	613	-.043	-.038	.073	-.128**	-							
6	*Children living at home*	.27	616	-.385**	.066	.031	-.063	.073	-						
7	*Storm surge experience*	.49	616	.204**	.001	.106**	.339**	-.041	-.111**	-					
8	*Flood experience*	.23	616	.081*	-.014	.009	.031	.016	.015	.051	-				
9	*Sea view*	.36	605	.068	-.021	-.025	-.317**	.163**	-.145**	-.081*	-.064	-			
10	*Ground floor*	.31	603	-.056	.038	.207**	.281**	-.055	.189**	.093*	.046	-.368**	-		
11	*Cellar*	.64	600	.018	.010	-.021	-.100*	.103*	-.064	-.053	.097*	.181**	-.134**	-	
12	*Location*	.35	619	.039	-.087*	-.025	-.466**	.198**	-.064	-.303**	.010	.301**	-.175**	.184**	-

* $p < .05$; ** $p < .01$. All correlations are Cramer's *V*, except for the correlations with Age, which are Pearson's *r*.

5.4.2 Regression analysis

We used multiple regression analyses to test the five hypotheses. The following hierarchical testing procedure was used. Model 1 tested for the partial effects of location (i.e., Hypothesis 1), socio-demographic characteristics (i.e., Hypothesis 2), and residence characteristics (i.e, Hypothesis 3) on risk perception. Model 2 tested for multiple mediation between location and risk perception via hazard experience variables (i.e., Hypothesis 4). Model 3 tested for the moderating effect of permanently residing on the relationship between location and risk perception (i.e., Hypothesis 5).

Table 5-5 depicts the results of the different models. Model 1 performance was relatively low with about 9.9 percent of variation in risk perception explained by the predictor set. The hypothesis stating that location is associated with perceived risk was confirmed. Since Oostende functioned as the reference category, the negative *B*-value indicated lower perception levels in Knokke-Heist and De Panne compared to Oostende. As indicated by the squared part correlations, two out of six socio-demographic characteristics, namely age and gender, were also found to contribute uniquely to the prediction of risk perception thereby confirming the second hypothesis. As denoted by the positive *B*-value, older respondents tend to have a higher perceived level of flood risk. Gender was also linked to a positive *B*-value, indicating higher levels of risk perception for women than for men. The prediction of risk perception from the three residence characteristics proved non-significant, thereby disconfirming the third hypothesis.

A marginal improvement was found for the percentage of explained variance in risk perception after hazard experience variables were added to Model 1 ($\Delta R^2_{\text{Model 2}} = 0.008$, $p = 0.08$). Model 2 functioned as a multiple mediation test for the effect of location on risk perception via hazard experience variables. The significance of the reduction in *B*-value for location between Models 1 and 2 is equivalent to the significance of the total indirect or multiple mediating effect through hazard experience variables (Hypothesis 4). A bootstrapping procedure was used to investigate the statistical significance of the total and partial indirect effects (Preacher and Hayes, 2008). Bootstrapping is an alternative method to the widely used Sobel test for testing mediation, as advocated by Baron and Kenny (1986). Bootstrapping is a nonparametric resampling procedure in which indirect effects are repeatedly estimated (e.g., 5,000 times) to create a non-normal distribution of the indirect effect estimates. This distribution is then used to construct asymmetric confidence intervals (CIs) around the point estimates (*PE's*) of the indirect effects. We reported on the 95% bias-corrected and accelerated (BCa) CIs which signalled significance of indirect effects when zero was not contained in the intervals. The PE of the total indirect effect was not significantly different from zero (*PE* = -0.01, SE = 0.03) with 95% confidence (BCa 95% CI of -0.06 to 0.04). Similar results were obtained for the partial indirect effects related to storm surge (BCa 95% CI of -0.06 to 0.03) and flood experiences (BCa 95% CI of -0.01 to 0.03), respectively. In conclusion, hazard experience variables did not mediate the effect of location on risk perception. Instead, flood (but not storm surge) experience independently predicted risk perception.

A slight improvement was found for the percentage of explained variance in risk perception after the moderating effect of permanently residing on the relationship between location and risk perception was added to Model 2 ($\Delta R^2_{\text{Model 3}} = 0.006$, $p = 0.06$). Following the procedure indicated by Aiken and West (1991), an interaction term was calculated between location and permanently residing. Tourists functioned as the reference category. For tourists, the simple effect for location indicated lower perception levels in Knokke-Heist and De Panne ($M_{\text{adjusted}} = -0.21$) compared to Oostende ($M_{\text{adjusted}} = 0.26$). A rerun of Model 3 with the dummy coding for permanently residing reversed indicated equal perception levels (B = -0.08, $p = .54$) for inhabitants in Knokke-Heist and De Panne ($M_{\text{adjusted}} = -0.03$) compared to Oostende ($M_{\text{adjusted}} = 0.05$). The difference in the simple effects of location on risk perception between tourists and inhabitants indicated a marginal significant interaction effect (identical to $\Delta R^2_{\text{Model 3}}$) of permanently residing and location in predicting risk perception.

In sum, risk perception is higher when respondents are older, female, have flood experience, and are tourists visiting Oostende.

Table 5-5 Regression analysis

		B	*SE B*	Beta	*t*	*p*	squared part corr. (%)
Model 1							
	Location	-0.21	0.10	-0.10	-2.08	0.04	0.7
	Age	0.02	0.00	0.21	4.67	0.00	3.4
	Gender	0.32	0.09	0.15	3.73	0.00	2.2
	Home ownership	0.11	0.10	0.05	1.10	0.27	0.2
	Permanent residence	0.02	0.11	0.01	0.20	0.84	0.0
	Education	-0.09	0.08	-0.04	-1.05	0.30	0.4
	Children living at home	-0.15	0.10	-0.07	-1.53	0.13	0.4
	Sea view	-0.12	0.10	-0.06	-1.23	0.22	0.2
	Ground floor	0.06	0.10	0.03	0.57	0.57	0.0
	Cellar	0.08	0.09	0.04	0.90	0.37	0.1
Model 2							
	Location	-0.20	0.10	-0.09	-1.93	0.05	0.6
	Age	0.01	0.00	0.19	4.26	0.00	2.8
	Gender	0.32	0.09	0.15	3.70	0.00	2.1
	Home ownership	0.12	0.10	0.05	1.12	0.26	0.2
	Permanent residence	0.01	0.11	0.00	0.08	0.94	0.0
	Education	-0.09	0.08	-0.05	-1.12	0.26	0.2
	Children living at home	-0.16	0.10	-0.07	-1.59	0.11	0.4
	Sea view	-0.10	0.10	-0.05	-1.08	0.28	0.2
	Ground floor	0.05	0.10	0.02	0.51	0.61	0.0
	Cellar	0.06	0.09	0.03	0.67	0.50	0.1
	Storm surge experience	0.06	0.09	0.03	0.64	0.52	0.1
	Flood experience	0.21	0.10	0.09	2.14	0.03	0.7
Model 3							
	Location	-0.47	0.18	-0.22	-2.66	0.01	1.1
	Age	0.01	0.00	0.20	4.33	0.00	2.9
	Gender	0.31	0.09	0.15	3.62	0.00	2.0
	Home ownership	0.12	0.10	0.05	1.15	0.25	0.2
	Permanent residence	-0.22	0.16	-0.10	-1.32	0.19	0.3
	Education	-0.09	0.08	-0.04	-1.03	0.30	0.2
	Children living at home	-0.16	0.10	-0.07	-1.58	0.12	0.4
	Sea view	-0.11	0.10	-0.05	-1.12	0.26	0.2
	Ground floor	0.05	0.10	0.02	0.54	0.59	0.0
	Cellar	0.06	0.09	0.03	0.68	0.50	0.1
	Storm surge experience	0.06	0.09	0.03	0.68	0.50	0.1
	Flood experience	0.21	0.10	0.09	2.15	0.03	0.7
	Location X Permanent residence	0.39	0.21	0.14	1.88	0.06	0.5

N = 584

5.5 Discussion

In this chapter, we have examined the public perception of coastal flood risks on the Belgian coast. To this end, a set of variables was considered in relation to risk perception, namely location, hazard experiences, socio-demographic characteristics and residence characteristics. Through hierarchical testing of three regression models, five hypotheses were tested.

In Model 1, partial effects of location, socio-demographic characteristics and residence characteristics were investigated on risk perception. Consistent with Hypothesis 1, we found that levels of risk perception varied significantly across location. In the city of Oostende, higher levels of risk perception were measured than in Knokke-Heist and De Panne. The higher level of risk perception in Oostende corresponds to the expert's risk estimates. Our findings suggest that the differences between expert and lay people might be smaller than often reported (Rowe and Wright, 2001; Wright *et al.*, 2002). This should be interpreted with caution, however, given that only two locations were considered in our study. Additional empirical research will be necessary to confirm these findings in the context of coastal flood risks.

Consistent with Hypothesis 2, age was positively correlated with perception of coastal flood risks. Older respondents scored on average higher on the different perception characteristics than younger people. This is in line with Grothmann and Reusswig (2006), who have found similar effects for people in flood-prone areas. Also consistent with Hypothesis 2, female gender was positively correlated with risk perception. Women's risk averse behaviour tends to have repercussions on the perception of coastal flood risks as well. This is in line with perception research on natural hazards in general, and on flood hazards in particular (Lindell and Hwang, 2008). Interestingly, home ownership was not related to risk perception. Resident owners and tenants exhibited similar levels of perceived flood risks, which is at variance with earlier research (Grothmann and Reusswig, 2006; Burningham *et al.*, 2008). This different outcome may be due to alternative methods of measuring risk perception. While Burningham *et al.* (2008) focused on risk awareness, Grothmann and Reusswig (2006) measured perceived ability to take protective actions regarding flood risks. Finally, effects of residing permanently on the coast were tested in this study. Based on previous research (Burningham *et al.*, 2008; Lindell and Hwang, 2008), it was hypothesized that inhabitants would have higher levels of flood risk perception than residential tourists. Regression analysis, however, revealed no significant effect of permanent residence on perceived risk levels.

Apart from location and socio-demographic characteristics, three additional factors regarding residence setting were tested, namely visibility of the sea, having a cellar and living on the ground floor. Against the expectations, none of these variables showed a significant effect on risk perception, thereby disconfirming the third hypothesis. A possible explanation for the outcomes of 'cellar' and 'ground floor' might be that the items which measured risk perception did not explicitly focus on property value and material belongings. As such, personal damage to property in cellars or ground floors were possibly not accurately measured. We could further not elucidate the discrepancy present in literature regarding hazard visibility. The visibility of the sea might have an effect on risk perception, but we were not able to measure it.

Model 2 tested for multiple mediation between location and risk perception via two hazard experience variables: storm surge experience and flood experience (Hypothesis 4). A mediation effect was not found, although a partial effect on risk perception was observed for flood experience. Apparently, the effect of location on risk perception is determined by other (psychological) processes, which were not measured in this study. One process, for example, might be that public works to coastal defences – such as beach nourishment – were mainly executed in Oostende during the last years. The visual impact of these public works may cause higher levels of perceived risk. This could be an element for further research.

The rationale for Model 3 (Hypothesis 5) was that residents of Oostende will exhibit a higher risk perception because they are at higher risk. For residential tourists, this effect should be absent. However, the opposite was found in the analysis. Instead of inhabitants, residential tourists in Oostende appear to have a higher risk perception compared to other municipalities. Possible explanations for this finding may be a certain habituation of inhabitants towards the risks of storm surges or risk priming effects in the case of tourists. More research is necessary to clarify this issue.

Some methodological limitations of the current study must be acknowledged. First, bias can arise from non-response. People who decide not to fill in the questionnaire may have informative reasons not to do so. Second, the survey was restricted to only three municipalities on the Belgian coast. General conclusions for the entire Belgian coast – or other coastal areas – are therefore to be drawn with circumspection. Third, the regression model accounts for a relatively low percentage of the variance, suggesting the presence of noise or variation when examining risk perception (Peacock *et al.*, 2005), and/or the missing of important variables, as suggested earlier in this discussion. We acknowledge here that although significant effects are found for individual characteristics, effect sizes remain marginal. These outcomes support earlier research by Lindell and Perry, (2000), who discussed on the significant but small effects of demographic variables on seismic risk perceptions.

Despite its limitations, the present study has provided increased insights into the public perceptions of coastal flood risks. Our findings suggest that older people, women and people with flood experience have higher perceived levels of coastal flood risks. Regarding location, consistency was found between expert's risk estimates and public risk perception, although the effect of location on risk perception is nuanced through the moderating effect of respondent type. Tourists visiting Oostende show higher levels of risk perception than tourists visiting the other municipalities. Future work may examine the different responses to flood hazards between inhabitants and residential tourists in further detail. Consequently, governmental risk awareness programs should be content specific, and tuned upon the specific target group to be affected. Insights in the psychological processes of different target groups influencing risk perception is therefore of vital importance. For example, our study revealed that the effect of location is not mediated by hazard experience, but tends to be determined by other (psychological) processes. We believe these and future findings may advance the communication between experts and citizens regarding coastal flood risks.

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6 THE INFORMED SOCIETY: AN ANALYSIS OF THE PUBLIC'S PREFERENCES, NEEDS AND SEEKING BEHAVIOUR REGARDING COASTAL FLOOD RISKS

Modified from: *Kellens, W., Zaalberg, R., De Maeyer, P., 2011. The informed society: An analysis of the public's preferences, needs and seeking behaviour regarding coastal flood risks. (under review for publication in Risk Analysis)*

Abstract

Recent flood risk management puts an increasing emphasis on the public's risk perception and its preferences. It is now widely recognized that a better knowledge of the public's awareness and concern about risks is of vital importance to outline effective risk communication strategies. Models such as RISP (Risk Information Seeking and Processing) address this evolution by considering the public's needs and their information seeking behaviour with regard to risk information. This chapter builds upon earlier information seeking models and focuses on the empirical relationships between information seeking behaviour and the constructs of risk perception, perceived hazard knowledge, response efficacy and information need in the context of coastal flood risks. Specific focus is given to the mediating role of information need in the model and to the differences in information seeking behaviour between permanent and temporary residents. By means of a structured on-line questionnaire, a cross-sectional survey was carried out in the city of Oostende, one of the most vulnerable places to coastal flooding on the Belgian coast. Three hundred thirteen respondents participated in the survey. Path analysis reveals that information need does not act as a mediator in contrast to risk perception and perceived knowledge. In addition, it is shown that risk perception and perceived hazard knowledge are higher for permanent than temporary residents, leading to increased information seeking behaviour among the former group. Finally, information preferences regarding flood risks are qualitatively discussed in the form of an addendum. Implications for risk communication are also given.

6.1 Introduction

The last two decades have witnessed an increasing interest in research on risk perception and risk communication with regard to flood hazards. By determining and analyzing the opinion of the general public on flood risks and their preferences for mitigation measures and adjustments, risk perception research has gradually taken a definite position in flood risk management (Renn, 1998; Schanze, 2007). In addition, the communication about these flood risks is evolving to strategies which enhance information-sharing, bottom-up activity and partnership development (ter Huurne and Gutteling, 2009; Stewart and Rashid, 2011). In his White Paper on Risk Governance, Renn (2005) underlines the importance of adjusting risk communication to the specific needs of the people. As such, people are given the possibility to judge their own risk situation and to make informed decisions and actions regarding preparedness and personal safety measures.

In search for tools or means that enhance this self-protective behaviour, a field of studies has focused on examining the determinants of information seeking behaviour, which is generally acknowledged as an important precursor of self-protective behaviour (Mileti and Darlington, 1997; Paton *et al.*, 2001; Kievik and Gutteling, 2011). Griffin and colleagues (1999) defined information seeking behaviour as the effort to acquire information in response to a need or perceived gap in ones knowledge. Various models have been suggested to explain people's seeking behaviour regarding risk information, such as the Risk Information Seeking and Processing model (RISP; Griffin *et al.*, 1999), the Framework for Risk Information and Seeking (FRIS; ter Huurne, 2008) and the Planned Risk Information Seeking Model (PRISM; Kahlor, 2010). To date, only two studies have applied such models to flood risks. Griffin *et al.* (2008) adopted the RISP model and focused on citizen's feelings of anger at managing agencies. Kievik and Gutteling (2011) employed parts of the FRIS model to test the effect of simple risk communication tools on people's seeking intentions and their self-protecting behaviour. However, both studies contained limitations. Since Kievik and Gutteling (2011) focused on just two predictors of information seeking behaviour (i.e., risk perception and efficacy beliefs), other important predictors or relationships remained out of scope. Griffin *et al.* (2008), from their part, did not test mediating relationships, although many are suggested in the proposed models.

Distinctive for the information seeking models is the central role for the level of information insufficiency or information need. Hence, the degree to which a person perceives information need is assumed to determine his/her seeking behaviour. In turn, information need is determined by other predictors, such as individual and hazard characteristics, risk perception, efficacy beliefs, current knowledge, etc. The central position of information need in these theoretical models clearly suggests a mediating role in the information seeking process (Griffin *et al.*, 1999; ter Huurne and Gutteling, 2008). However, past research did not fully succeeded in revealing the functioning of information need in information seeking behaviour, neither in a health risk context (Kahlor, 2010), nor in the context of flood risks (Griffin *et al.*, 2008).Therefore, our first research objective concentrates on the mediating properties of information need in the information seeking process.

Understanding the determinants of individual flood adjustments is not only important in terms of damage reduction and individual welfare, it is also a sensible counterweight to the governmental focus on flood adaptation measures. For example, flood risks are receiving increasing interest on the Belgian coast, since various measures (such as beach nourishment, storm walls, etc.) are being carried out to protect the coast against future extreme storm surges from the North Sea (cf. Master Plan for Coastal Safety; Mertens *et al.*, 2010)). To date, however, scarce attention has been given to citizens at risk and their information needs. One exception is the European COMRISK project (Kaiser *et al.*, 2004), which was conducted in 2004 (i.e., before the infrastructure works on the Belgian coast), and which revealed – among other things – that the Belgian public exhibits the highest demand for more information on coastal flood risks (78%), as compared to several other European countries (i.e., Denmark, Germany, The Netherlands and United Kingdom). The Belgian coast is therefore an intriguing area to probe the public's seeking behaviour with regard to coastal flood risk information.

Our second research objective is not only to extend our scientific knowledge on the public's attitudes regarding flood risks on the Belgian coast, but also to focus on a specific target group which is often completely overlooked in flood risk research, namely temporary residents. Several authors have suggested that this group of residents is more vulnerable to disaster situations than locals, because they are less familiar with local hazards and the resources that can be relied on to avoid risk (Burby and Wagner, 1996; Faulkner, 2001). This is especially true for temporary residents who own a second home on the coast, here referred to as second residence owners. The fact that three quarters of the overnight tourism on the Belgian coast is based on second residence tourism (Gunst *et al.*, 2008) signals its importance in terms of damage reduction and personal welfare in the case of floods. The present study explicitly considers both permanent residents (inhabitants) and temporary residents (second residence owners) and examines possible differences in their risk information need and risk information seeking behaviour.

In sum, this chapter builds upon previous information seeking models and contributes to a better understanding of the relationships between information seeking behaviour and its main determinants in the context of coastal flood risks. Particular attention is given to the mediating relationship of information need and to the effects of residing permanently in a flood-prone area or not. In addition, preferences regarding flood risk information are qualitatively discussed in an addendum. Area of interest throughout the study is the city of Oostende, which is known as one of the most vulnerable locations to coastal flooding on the Belgian coast (Kellens *et al.*, 2011).

6.2 Theoretical background

6.2.1 Overview of information seeking models

The study of information seeking behaviour has been the focus of the model of Risk Information Seeking and Processing (RISP), developed by Griffin and colleagues (1999). By adapting and synthesizing components from the Heuristic-Systematic Model (HSM; Eagly and Chaiken, 1993) and the Theory of Planned Behaviour (TPB; Azjen, 1991), the RISP model proposes that information insufficiency is the key factor that motivates people to seek for and process risk-related information. This information insufficiency is strongly correlated with hazard knowledge and is predicted by a set of factors, among which are individual characteristics (e.g., hazard experience) and risk perception (affective response).

Drawing further on the concepts of the original RISP model, ter Huurne and Gutteling (2008) proposed a framework which relates risk information seeking behaviour to self-efficacy, current knowledge (about hazards), risk perception and information need. An adapted version of the model was later referred to as the Framework of Risk Information Seeking (FRIS; ter Huurne, 2008). While RISP considers individual characteristics (such as age, gender and hazard experience), ter Huurne and Gutteling's model puts more emphasis on psychological characteristics, such as trust, self-efficacy and engagement as determinants of information seeking behaviour. Applied to industrial risks and hazard waste transportation risks, ter Huurne and

Gutteling (2008) found that information need, risk perception and current knowledge are direct predictors of the intention to seek risk information.

Kahlor (2010) brought several concepts from previous information seeking models together and formed the Planned Risk Information Seeking Model (PRISM), which treats risk information seeking as a deliberate (planned) behaviour. Main components in this model are risk perception, affective risk response, perceived knowledge and perceived knowledge insufficiency. In contrast to earlier models, Kahlor (2010) could not demonstrate a significant link between knowledge insufficiency and information seeking behaviour.

Finally, a recent study of Kievik and Gutteling (2011) showed that information seeking behaviour is particularly susceptible to levels of risk perception and efficacy beliefs. In an experimental study design, it was demonstrated that information seeking behaviour (and hence self-protective behaviour) can be stimulated with relatively simple risk communication tools that influence risk perception levels (by means of fear appeals) and efficacy beliefs (through message content). While this study did not test a comprehensive model, it showed the importance of risk perception and efficacy beliefs in the context of coping with flood risks.

Based on the above findings, several determinants of information seeking behaviour and their relationships come to the fore as important or at least as interesting items to scrutinize. Information need (or insufficiency) is deemed an essential factor in each model, yet its mediating role remains unclear (Griffin *et al.*, 1999; Griffin *et al.*, 2004; Griffin *et al.*, 2008; Kahlor, 2010). Risk perception and efficacy beliefs are considered crucial predictors of information seeking behaviour (ter Huurne and Gutteling, 2008; Kievik and Gutteling, 2011), but there relationship with information need is insufficiently examined. Another determinant included in almost every model is (perceived) hazard knowledge. However, both its relation with information need as well as its predicting role on information seeking behaviour are contested (Kahlor, 2010). Finally, several individual characteristics (e.g., age, gender, hazard experience) have been suggested in the original RISP model, but their actual influence in the complete information seeking process remains unsure (Griffin *et al.*, 1999; Griffin *et al.*, 2008). The next section discusses each of these determinants in more detail.

6.2.2 Determinants of information seeking behaviour

Information need. Information insufficiency or information need plays a central role in the audience-based risk communication approaches (ter Huurne, 2008). It is widely regarded as the key motivator to seek for risk information. Based on the sufficiency principle in the Heuristic-Systematic Model (Eagly and Chaiken, 1993), Griffin *et al.* (2008) define information insufficiency as the perceived 'gap' between current knowledge and sufficient knowledge (i.e. the threshold that one perceives as being sufficient). The less people know about a risk/hazard, or the higher their perception of the required knowledge level, the higher their need for risk-related information will be, and consequently their intentions to seek for additional information.

Perceived hazard knowledge. According to Griffin and colleagues' (2008) definition of information insufficiency, current or perceived knowledge is inherently part of insufficiency. Yet, others (ter Huurne and Gutteling, 2008; Kahlor, 2010) regard perceived knowledge as a separate variable that influences one's need for risk-related information. Lower perceived knowledge relates to higher information need and thus seeking intentions.

Risk perception. The study of the public risk perception has undergone a remarkable growth in the last decades, and is now represented in nearly every risk domain. While many elements have been related to risk perception (Fischhoff *et al.*, 1978; Slovic, 1987), some key elements have been generally used with regard to the prediction of information seeking behaviour. Griffin and colleagues (2008) defined risk perception as the combination of subjective judgments of a hazard's probability with the perceived severity of possible consequences. They further demonstrated that risk perception influences affective responses to a hazard, such as feelings of worry or anger (Griffin *et al.*, 2004; 2008). These definitions correspond to the two modes of thinking in risk perception (Slovic *et al.*, 2004), which distinguish between risk as analysis (analytical system) and risk as feelings (experiential system). While the former relies on normative rules and formal logic, the latter uses fast, intuitive decisions. Despite this theoretical distinction, several researchers have found a single risk perception scale, based on factor analysis (e.g., Terpstra *et al.*, 2006; Miceli *et al.*, 2008; Kellens *et al.*, 2011). Risk perception (including affective response) is generally regarded as a positive predictor for information need, even though some studies have demonstrated the opposite relation (e.g., Trumbo, 2002).

Efficacy beliefs. Risk communication researchers have stressed the importance of considering one's belief that he or she is able to understand and execute certain actions to cope with a hazard. This concept is well-known as self-efficacy (ter Huurne and Gutteling, 2008), and its positive effect on information seeking intentions has been reported several times (Griffin *et al.*, 2008; ter Huurne and Gutteling, 2008; Kievik and Gutteling, 2011). Related to self-efficacy is response efficacy, which denotes the perceived usefulness of information (e.g., advice) to successfully cope with a threat. Previous research (Kievik and Gutteling, 2011) has demonstrated strong correlations between self-efficacy and response efficacy, together referred to as efficacy beliefs. For reasons of simplicity, we will focus on just one type of efficacy in this study, namely response efficacy.

Individual characteristics. Socio-demographic variables are found in most studies of risk perception, but typically they are employed atheoretically and account for relatively little explained variance in information seeking behaviour (Griffin *et al.*, 1999; Griffin *et al.*, 2004). However, several studies have identified significant relations between risk perception and variables such as age and gender (e.g., Lindell and Hwang, 2008; Armas and Avram, 2009; Kreibich *et al.*, 2009; Kellens *et al.*, 2011). In addition, previous hazard experience has generally been found to increase risk perceptions (e.g., Keller *et al.*, 2006; Siegrist and Gutscher, 2006; Knocke and Kolivras, 2007; Lara *et al.*, 2010) and the likelihood that people adopt hazard adjustments (e.g., Grothmann and Reusswig, 2006; Thieken *et al.*, 2006). As such, individual characteristics may influence information need and information seeking intentions through risk perception. Griffin *et al.* (2004; 2008) also found effects of individual characteristics (e.g., education) on information need through perceived knowledge. To our knowledge, effects of residing permanently or temporary on a hazard-prone location have not yet been examined in the context of information seeking behaviour.

6.3 Research hypotheses

Figure 6-1 depicts a theoretical model of information seeking behaviour, which stems from the discussed determinants and their relationships in the previous section. In order to structure the analysis of the model, following hypotheses are defined:

> H1a/b: individual characteristics (a) and response efficacy (b) predict information seeking behaviour;

H2a/b/c: risk perception (a), perceived hazard knowledge (b), and information need (c) mediate the H1a effect;

H3a: information need mediates the relationship between risk perception and information seeking behaviour;

H3b: information need mediates the relationship between perceived hazard knowledge and information seeking behaviour;

H4: individual characteristics predict information need;

H5a/b: risk perception (a) and perceived hazard knowledge (b) mediate the H4 effect.

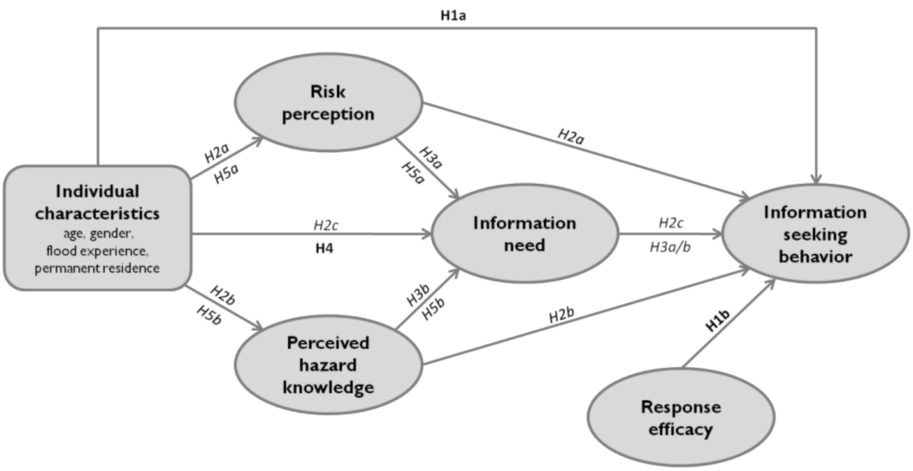

Figure 6-1 Hypothesized relationships among determinants of information seeking behaviour. Total effect relations (H1 and H4) are represented in bold; mediating relations (H2, H3 and H5) are represented in italic

6.4 Methodology

6.4.1 Study area and data collection

Area of interest in this study is the city of Oostende, which lies in a central position on the 65 km long Belgian coast (Figure 6-2). The Belgian coast is located along the Southern Bight of the North Sea and is characterized by sandy beaches, dune areas and hard defence structures such as groynes and sea walls. Due to the limited length of the coastline and the increasing population pressure, most of the coastal zone has become urbanized and half of the coastal dunes has disappeared (Charlier and Demeyer, 1992).

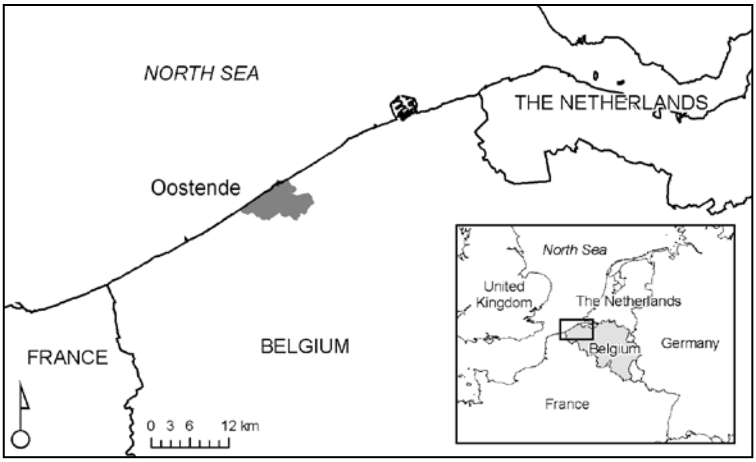

Figure 6-2 Location of Oostende on the Belgian coast

In the past, several storm surges have affected the Belgian coast. During the severe storm flood disaster of 1953, eight people died in the city of Oostende. According to the outcomes of the on-going Master Plan for Coastal Safety (Mertens *et al.*, 2010), the city centre of Oostende is still considered one of the most vulnerable parts of the Belgian coast. Even so, major efforts have been realized in the previous years with regard to beach nourishment and soft sea defences structures.

With a population number of approximately 69,000 inhabitants, Oostende is by far the largest place on the Belgian coast. The number of temporary residents is estimated above 20,000 during 'top days' in the summer holidays. Approximately 30% of this group is owner of a second residence. According to a recent study (Gunst *et al.*, 2008), owners stay on average about 54 nights per year in their second residence.

Data were collected during the month September 2010 by an on-line questionnaire, which was developed with the open source survey application LimeSurvey®. Adult permanent and temporary residents were invited to take part in the study through an invitation letter. These letters were systematically distributed in postboxes in a random selection of streets in the city of Oostende. Based on the outcomes of several worst-case scenarios (cf. Master

Plan for Coastal Safety; Mertens *et al.*, 2010), most of the territory of the city of Oostende can be regarded to be at risk of being (severely) flooded during an extreme storm surge. The belongings of all respondents are therefore assumed to be at equal chance of flooding.

6.4.2 Questionnaire characteristics

Table 6-1 presents all items that were used to measure the model components as depicted in Figure 6-1 (except for individual characteristics), together with their item statistics (mean and standard deviation) and factor loadings (see further).

In order to measure information seeking behaviour, respondents were asked to what extent they intended to search for information on four topics, (i) possible consequences of a storm surge, (ii) measures that the government is employing to cope with storm surges, (iii) possible escape routes in the case of threatening coastal floods, and (iv) safe locations in the neighborhood (scores 1 to 5, from 'definitely not' to 'definitely'). These topics are based on items to measure flood preparedness intentions, developed and used by Terpstra (2011). Perceived hazard knowledge was measured by four questions related to: (i) the consequences of a coastal flood, (ii) the use and functioning of beach nourishment, (iii) the protection level of the dikes and (iv) the maintenance of the sea defence. All four questions were introduced by 'How well do you think you're informed about…?' and answers ranged from 'very bad' (score: 1) to 'very good' (score: 5). Risk perception was measured through five items, which were based on previous research on public perceptions of coastal flood risks (Kellens *et al.*, 2011). The five items reflect different aspects of risk perception: awareness (or consciousness), likelihood, affect (worry), impact (storm surge consequences) and calmness (feeling safe). All items were measured on a 5-point scale, ranging from 'no agreement at all' (score: 1) to 'full agreement' (score: 5). Response efficacy was measured by the perceived level of usefulness of three information topics, (i) the sea defence and the actual protection level, (ii) tips and instructions on personal measures to mitigate flood damage and (iii) instructions about evacuation procedures and escape routes (scores 1 to 5, from 'not useful at all' to 'very useful'). Finally, information need or information insufficiency was measured by three dichotomous questions, (i) 'Do you think sufficient information is provided about the flood risks on the Belgian coast?', (ii) 'Have you ever searched for information about flood risks on the Belgian coast?', and (iii) 'Would you like to know more about flood risks on the Belgian coast?' (yes/no, coded as 1/0).

A closer look at the item statistics in Table I reveals remarkably high values for the items measuring information need. Particularly the question 'Would you like to know more about flood risks on the Belgian coast?' results in a manifest mean score of 0.92 (in which 'no' = 0; 'yes' = 1; SD = 0.26). Hence, 92% of our sample indicates that more information on coastal flood risks is necessary.

Exploratory factor analysis with correlated factors (oblimin rotation) revealed the existence of four factors which corresponded to four constructs (cf. Table 6-1). Since the items of information need were measured as dichotomies, they could not be included in the factor analysis. As far as the other items are concerned, all could be preserved except for one item regarding response efficacy of sea defence and actual protection level due to low cross-loadings. Internal consistencies (Cronbach's Alphas) were satisfactory for the four constructs. In order to facilitate further analysis, the items are summed together for each construct (plus information need), so that five scores are formed: (i) an information seeking behaviour score (range: 4 – 20), (ii) a perceived knowledge score (range: 4 – 20), (iii) a risk perception score (range: 5 – 25), (iv) an response efficacy score (range: 2 – 10), and (v) an information need score (range: 0 – 3). For reasons of simplicity, the term 'score' is not used in the remainder of the paper.

Finally, a small set of individual characteristics was gathered. Apart from age, gender (male/female, coded as 1/0), permanent and temporary residents were distinguished from each other by the question 'Do you reside permanently on the Belgian coast?' (yes/no, coded as 1/0). Flood experience was measured by a dichotomous question 'Have you ever suffered material and/or financial damage as a consequence of flooding (be it on the coast or elsewhere)?' (yes/no, coded as 1/0).

Table 6-1 Factor loadings and item statistics for all items

Items	**Factor loadings**				**Item statistics**	
	I	**II**	**III**	**IV**	**Mean**	**SD**
1. Information seeking behaviour (α = .89)					**13.98**	**3.60**
To what extent do you intend to search for more information on:						
- possible consequences of a storm surge;	**0.83**			-0.21	3.42	0.93
- measures that the government is employing to cope with storm surges;	**0.87**				3.61	0.96
- possible escape routes in the case of threatening coastal floods;	**0.75**			0.33	3.40	1.10
- safe locations in the neighborhood.	**0.70**			0.31	3.41	1.14
2. Perceived hazard knowledge (α = .94)					**9.86**	**4.08**
How well do you think you're informed about...?						
- the consequences of a coastal flood;		**0.81**			2.42	1.12
- the use and functioning of beach nourishment;		**0.91**			2.74	1.20
- the protection level of the dikes;		**0.95**			2.55	1.11
- the maintenance of the sea defence.		**0.87**			2.40	1.09
3. Risk perception (α = .78)					**15.65**	**3.76**
- I sometimes give flood risks on the Belgian coast a moment thought. (awareness)			**0.63**		2.46	0.96
- I expect great chances of storm surges causing floods in the coastal area. (likelihood)			**0.77**	-0.11	3.24	1.13
- I'm worried about the danger of a storm surge on the Belgian coast. (affect)			**0.90**		3.08	1.20
- A storm surge can have fatal consequences for the coastal area and its inhabitants. (impact)			**0.51**		3.78	1.02
- When I stay on the Belgian coast, I feel protected by the sea defences. (calmness)*		0.19	**-0.36**		3.37	0.95
4. Response efficacy (α = 0.74)					**8.16**	**1.87**
To what extent may the following information topic be useful to you:						
- the sea defence and the actual protection level	0.12		0.13	0.14	4.06	0.79
- tips and instructions on personal measures to mitigate flood damage				**0.55**	3.96	1.12
- instructions about evacuation procedures and escape routes				**0.98**	4.10	1.07

Items	Factor loadings				Item statistics	
	I	II	III	IV	Mean	SD
5. Information need**					**2.12**	**0.51**
- Do you think sufficient information is provided about the flood risks on the Belgian coast?*	-	-	-	-	0.16	0.37
- Have you ever searched for information about flood risks on the Belgian coast?	-	-	-	-	0.22	0.42
- Would you like to know more about flood risks on the Belgian coast?	-	-	-	-	0.92	0.26

* Item reverse coded; ** not considered in factor analysis (items are dichotomous); Except for information need, all items are measured on a 5-point scale with 3 as middle value; Factor loadings below 0.1 are not shown; *N* = 266

6.4.3 Sample characteristics

A total of 313 respondents filled out the questionnaire, leading to a response rate of 6.3%. This low response rate is not unusual for on-line questionnaires (Terpstra, 2010) and does not necessarily result in biased estimates in the statistical analysis (Lindell and Perry, 2000). Caution, however, should be made when making generalizations.

The sample consists of 251 permanent residents (79.4%) against 62 temporary residents (second residence owners). This marked dissimilarity in sample size closely matches the actual ratio between permanent and temporary residents at the time the questionnaire was on-line (on average 86% of the coastal population in September are permanent residents, according to data of West Flanders Economic Agency; Gunst *et al.*, 2008). The overall mean age of the sample is 54.6 years old, which is slightly biased towards older people (average age in Belgium is 49 years among adults (> 18 years old)). Male respondents are overrepresented (65.1%). As regards flood experience, only 7% of the sample has suffered financial/material damage from previous flooding.

6.4.4 Analysis

In order to test the set of hypotheses from Section 3, a path analysis is conducted using PRELIS 2.30 and LISREL 8.30 software (Jöreskog and Sörbom, 1993). PRELIS was used to calculate the correlation and standard deviation matrices of the theoretical concepts as presented in the theoretical model (n = 243 with list-wise deletion of cases). Both matrices then served as data input for the path analysis using LISREL, in which the covariance matrix was analyzed using maximum likelihood estimation. Multiple fit indices are reported to evaluate the adequacy of overall model fit. Adequate model fit is based on the Hu and Bentler cutoff criteria for fit indexes in covariance structure analyses (Hu and Bentler, 1999). Preferably, the χ^2/degrees of freedom (df) ratio is smaller then 2, the Comparative Fit Index (CFI) is larger then 0.90, the Root Mean Square Error of Approximation (RMSEA) is smaller than 0.08 while the complete RMSEA 90 percent confidence interval is smaller than 0.10. Finally, the Standardized Root Mean square Residual (SRMR) should be smaller than 0.10.

Besides overall model fit, LISREL output also generates unstandardized regression weights (i.e., B's) for direct effects between theoretical concepts, together with their significance levels in the form of so-called *t*-statistics. A *t*-statistic of 1.96 absolute or larger is significantly different from zero at the 0.05 level (two-sided). A *t*-statistic of 2.58 absolute or larger is significantly different from zero at the 0.01 level (two-sided). Mediation testing is done by investigating the significance of single indirect effects in the case of one mediator or multiple indirect effects in the case of three mediators. Multiple indirect effects sum up to total indirect effects, as produced by the LISREL software. Direct and total indirect effects sum up to total effects. When total indirect effects are zero, then direct and total effects are alike. For example, based upon the theoretical model proposed in this study, efficacy directly predicts information seeking behaviour without intervening concepts. Direct and total effects should therefore be equal for this relationship.

6.5 Results

Based upon an unmediated model, information seeking behaviour is predicted by individual characteristics (H1a) and response efficacy (H1b). Figure 6-3 depicts the unstandardized regression weights (*t*-statistics between brackets) for the total effects of individual characteristics and efficacy predicting information seeking behaviour. The first hypothesis is confirmed, because information seeking behaviour is enhanced when respondents are older, live permanently on the Belgian coast, and consider risk information useful. However, the total effects of previous flood experience and gender are not significantly related to information seeking behaviour. Model fit was adequate with a χ^2/df ratio of 1.58, a CFI of 0.98, a RMSEA of 0.048, an RMSEA confidence interval ranging from 0.00 to 0.10, and a SRMR of 0.037.

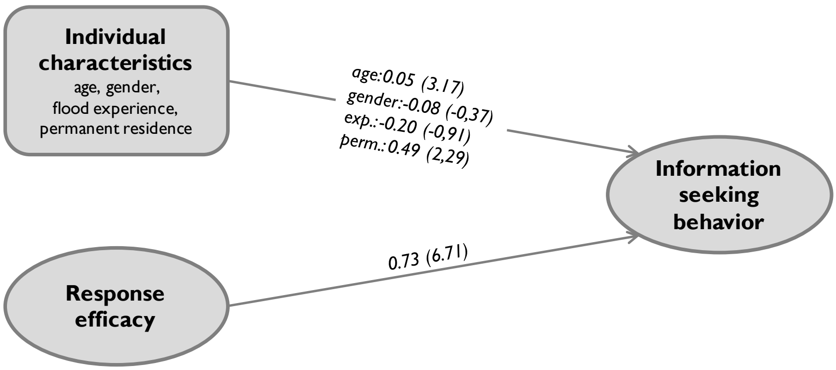

Figure 6-3 Unmediated model: B values of total effects (t-statistics between brackets)

The LISREL output also allows us to test the second hypothesis concerning mediation. The total effects of age and residing permanently on information seeking behaviour are mediated by risk perception (H2a), perceived hazard knowledge (H2b), and information need (H2c). Figure 6-4 depicts the unstandardized regression weights (*t*-statistics between brackets) of all the direct effects in the mediated model. As can be seen in Figure 6-4, the direct effect of age on information seeking behaviour remains significant, after controlling for multiple mediating processes. More importantly, the total indirect effect is significantly different from zero signaling partial mediation, $B_{\text{total indirect effect}} = 0.01$, $p < .05$. Careful inspection of the multiple intervening processes reveals that age is significantly associated with risk perception, but not with perceived hazard knowledge and information need ($B_{\text{total effect}} = 0.00$, *ns*). Risk perception increases for older respondents. Risk perception in turn is significantly associated with information seeking behaviour, $B_{\text{total effect}} = 0.22$, $p < .01$. Information seeking behaviour is enhanced when risk perception increases. In sum, the total age effect on information seeking behaviour is partly mediated through risk perception confirming H2a, but disconfirming hypotheses 2b and 2c.

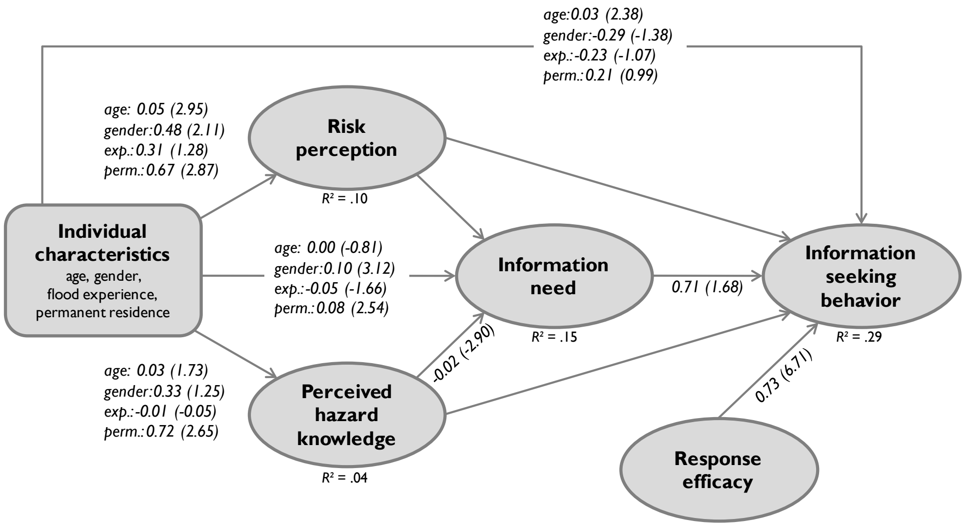

Figure 6-4 Mediated model: B values of direct effects (t-statistics between brackets)

The direct effect of residing permanently on information seeking behaviour is non-significant, while the total indirect effect differs from zero, $B_{\text{total indirect effect}} = 0.28$, $p < .01$. A closer examination of the intervening processes reveals that residing permanently is significantly associated with risk perception, perceived knowledge, and information need ($B_{\text{total effect}} = 0.09$, $p < .01$). Residents living permanently on the Belgian coast have higher risk perception, higher perceived hazard knowledge, and greater information need, compared to temporary residents. As stated above, increasing risk perception increases information seeking behaviour, $B_{\text{total effect}} = 0.22$, $p < .01$. Similarly for perceived hazard knowledge, $B_{\text{total effect}} = 0.11$, $p < .05$. However, the association between information need and information seeking behaviour is non-significant. In sum, the total effect of residing permanently on information seeking behaviour is completely mediated through risk perception and perceived knowledge confirming H2a and H2b. Information need is not a mediator in this relationship, thereby disconfirming H2c.

Information need does not mediate the relationship between risk perception and information seeking behaviour. The indirect effect was non-significant ($B_{\text{indirect effect}} = 0.02$, *ns*), thereby disconfirming H3a. Similarly, information need does not mediate the relationship between knowledge and information seeking behaviour ($B_{\text{indirect effect}} = -0.02$, *ns*), thereby disconfirming H3b. In sum, information need is again not a mediator due to the non-significant relationship with information seeking behaviour.

According to H4, the individual characteristics under study (age, gender, flood experience and permanent residence) are expected to predict information need. This hypothesis is only partly confirmed, because information need is enhanced for men ($B_{total\ effect} = 0.11$, $p < .01$), and when respondents live permanently on the Belgian coast ($B_{total\ effect} = 0.09$, $p < .01$). However, the total effects of previous flood experience ($B_{total\ effect} = -0.04$, *ns*) and age ($B_{total\ effect} = 0.00$, *ns*) are not significantly related to information need.

Finally, the total effects on information need are mediated by risk perception (H5a), and perceived hazard knowledge (H5b). As can be seen in Figure 6-4, the direct effect of residing permanently remains significant on information need. The total indirect effect is non-significant ($B_{total\ indirect\ effect} = 0.01$, *ns*). Careful inspection of the intervening paths via risk perception and perceived knowledge explains this null effect. The intervening path through risk perception is positive while the intervening path through perceived knowledge is negative. Both indirect effects suppress each other, making the total indirect effect zero. A similar suppressor effect is found for the gender-need relationship. The total indirect effect is again non-significant, $B_{total\ indirect\ effect} = 0.01$, *ns*. In sum, residents living permanently on the Belgian coast and men have greater information need than temporary residents and women. Mediation processes via risk perception and perceived knowledge cancel each other out.

6.6 Discussion

This chapter dealt with the public's information seeking behaviour in the context of coastal flood risks. Based on previous information seeking models, empirical relationships were tested between information seeking behaviour and a set of determinants. Particular attention was given to the mediating role of information need and the effects of residing permanently on the coast (or not) in the information seeking process. A sample of 313 respondents (inhabitants and second residence owners) was collected in the city of Oostende on the Belgian coast. Path analysis was used to statistically test several hypotheses, which reflected the different relationships of the hypothesized model (cf. Figure 6-1). This section discusses the main outcomes of the study and provides interpretations and additional clarification to these outcomes.

The first research objective of this chapter concentrated on the role of information need as being a mediator in the seeking process of risk related information. Previous models, such as RISP (Griffin *et al.*, 1999) and FRIS (ter Huurne, 2008) suggested mediation by placing information need (or information insufficiency) in the centre of these models. However, our results suggest that information need does not fulfil a mediating role in the information seeking process. The direct effect from information need on information seeking behaviour was non-significant. As a result, the indirect effects via information need were also non-significant. Our findings seem to support the outcome of Kahlor (2010), who could not find a significant effect of perceived knowledge insufficiency (comparable to information need) on seeking intentions either. Apparently, perceiving an information need does not necessarily result in higher seeking intentions. Responsibility might be the key variable to explain this insignificant relation. For instance, a person might feel he is insufficiently informed about a hazard, but beliefs it is not his responsibility to inform himself about it. Instead, this person beliefs the government should actively communicate about risks. Previous research has examined similar relations. For example, Lindell and Perry (2000) reported significant correlations between perceived protection responsibility and the adoption of adjustments in the context of seismic hazards. To our knowledge, however, no study has yet investigated the moderating role of responsibility in the need-intention relationship. This might be a topic for future research.

The second research objective of this chapter focused on the effects of residing permanently in the coastal area or not, given that the temporary residents own a second home in the coastal area. Although both groups (inhabitants and second residence owners) have belongings to be concerned of in the coastal area, they largely differ in terms of 'being present', making the temporary residents much more difficult to reach or to inform. The outcomes of our model suggested that permanent residents have higher risk perception, higher perceived hazard knowledge, and greater information needs than temporary residents. Most importantly, residing permanently or temporary along the coast affected information seeking behaviour via risk perception and hazard knowledge, indicating full mediation. Hence, inhabitants are more than second residence owners inclined to seek for information on coastal flood risks, because they feel more vulnerable and have greater knowledge of the risks of coastal flooding.

In addition to the two research objectives, several other outcomes are worth mentioning here. In support of previous research by Kievik and Gutteling (2011), risk perception and response efficacy were found to be strong predictors of information seeking behaviour. This outcome again suggests that risk communication should focus on raising risk perception (e.g., using fear appeal messages) together with persuasive messages to increase response efficacy. Apart from permanent residence, age was found the only strong predictor among the individual characteristics under study. The model indicated partial mediation since age predicts information seeking behaviour both directly and indirectly via risk perception. This outcome supports previous studies on flood risk perception, which showed that older people generally exhibit higher levels of risk perception for such hazards (Lindell and Hwang, 2008; Kellens *et al.*, 2011). To our surprise, flood experience was not a significant predictor of seeking intentions. We believe the small subsample of people having such experience ($N = 18$) prevented us from revealing significant relations with other variables.

A specific issue encountered in our model is suppression of the total indirect effect via risk perception and perceived knowledge. We found such suppression effects for the relationships between gender, permanent residence and information need. While higher levels of risk perception increase information need, perceived hazard knowledge equally decreases information need. To our knowledge, no study previously reported on mediating processes opposing each other.

Some limitations of this study need to be acknowledged here. A first limitation concerns the model fit and the variance explained by the determinants. While our main goal was to examine several relationships between determinants of information seeking behaviour, we believe the model we presented is adequate. Model fit parameters are satisfactory, just as the explained variance of information seeking behaviour is (29%). A higher explained variance might have been possible by inclusion of other variables (e.g., perceived responsibility). A second limitation deals with the response rate of the survey. As Lindell and Perry (2000) indicate, low response rates might make the representativeness of a sample uncertain because non-response might be systematic rather than random. We suppose two main reasons for this low response rate. Due to privacy issues and the temporary subsample of second residence owners, it was not possible to invite people personally via email, nor was it possible to send out reminders. A third limitation concerns causality testing. Despite the suggested directions in our model, the cross-sectional sample data did not allow for causality testing. While we can rely on previous (quasi-) experimental studies and theories to assume that several directions are indeed correct (e.g., the causal effects of risk perception and response efficacy on information seeking behaviour have been proven by Kievik and Gutteling (2011)), caution should be made when linking up causal connections of specific relations (Lindell and Hwang, 2008). Finally, focus in this study was on information seeking behaviour and its determinants. However, increasing information seeking behaviour among citizens is only useful if it makes people more resilient and prepared for a hazard. Previous studies have already demonstrated strong links between information seeking intentions and preparedness behavior (cf. Mileti and Darlington, 1997; Paton *et al.*, 2001; Kievik and Gutteling, 2011), but future research should further investigate the determinants and/or include the latter as well.

Despite these limitations, the present study provides new insights in the people's information seeking process regarding coastal flood risks. Based on cross-sectional data, information need could not be detected as a mediator, nor as a predictor of information seeking behaviour. This is important, since it shows that a high information need among the public not necessarily transfers itself into increased seeking intentions or even desirable behaviour. Thus, although respondents from Oostende showed high information needs (92% indicated more information on coastal flood risks is welcome, cf. Table I), governments should not rest on their laurels, since risk communication programs will be indispensable to fulfill the public's need. Moreover, it seems that people's information need is increasing in recent years, when comparing the current information need to the findings of the COMRISK project (in which 78% of the respondents indicated an information insufficiency; Kaiser *et al.*, 2004). It seems reasonable to assume that the recent defence works on the Belgian coast (e.g., extensive beach nourishments) have increased awareness levels among the public which consequently have provoked their information need. Examining such (visual) effects might be a matter for future research.

Finally, this study showed that the lower information seeking behaviour among temporary residents can be perfectly countered, since full mediation is present through risk perception and perceived knowledge. Communication campaigns should pay special attention to temporary residents, focusing on increasing their awareness and knowledge about coastal flood risks, thereby increasing their information seeking behaviour indirectly.

Addendum: Public's preferences of flood risk communication

Introduction

Risk communication covers a wide range of activities, such as informing and educating the public about risk and risk management in order to influence attitudes and behaviour, acting in situations of emergency or crises, aiding in decision-making and assisting in conflict resolution (Boholm, 2008). Effective risk communication, or the non-existence thereof, can have a major bearing on how well people are prepared to face and cope with a risk (Basic, 2009).

Many researchers have examined *the do's and don'ts* of risk communication. First of all, it is widely accepted that risk communication should strive for a dialogue between all possible actors – policy makers, flood risk experts, stakeholders, public, etc. A crucial condition for this dialogue to be successful is trust (Petts, 2008). As a kind of oil, trust lubricates the contacts between the participants and creates a *smooth* communication. However, as Slovic (1997) alerts, trust is easier to destroy than to create. It is therefore important for the communicator to listen to the audience, and to share some decision power through stakeholder participation (Bier, 2001). Apart from the source, the message channel is equally important to build trust (Lindell and Hwang, 2008). Risk-related information should further be clear and unambiguous at all times (McEwen *et al.*, 2002), a task which is not as easy as it sounds, particularly with regard to low-probability risks such as flood hazards. Visschers *et al.* (2009) reviewed the use of probability information and uncertainty in risk communication and found that the presentation format of the information is particularly important when people have less time, or are less motivated to process the information. However, the content of the message should not be overlooked either. Terpstra *et al.* (2010) found that the public prefers specific rather than generic information. While the latter is usually employed, the former may be more effective since it provides personal information such as advice on mitigation measures, evacuation procedures, etc. An underestimated factor in effective risk communication is repetition. As people tend to rapidly forget information that is related to rare events (Plate, 2007), repeating the risk information on a regular basis is deemed essential. Finally, a number of authors recognize the importance of considering the heterogeneity of the public in risk communication (Martens *et al.*, 2009).

This addendum aims to reveal the public's preferences regarding coastal flood risk information. Particularly, three questions are addressed here, namely a *what-*, *when*, and *how*-question: (i) '*What* information is felt useful?', (ii) '*When* should this information be disseminated?', and (iii) '*How* should this information be disseminated?' Additionally, reasons for declining flood risk information are examined. Specific attention is given to differences between permanent and temporary residents.

Methodology

Descriptive analysis is carried out on cross-sectional data, gathered in the city of Oostende, one of the most vulnerable places to coastal flooding on the Belgian coast. We refer to Section 6.4.1 for a description of the sampling method and the sample characteristics.

This addendum reuses the questionnaire items on response efficacy, which measured the perceived usefulness of several information topics (cf. Section 6.4.2). In addition to these items, three questions probed the preferred information frequency (weekly, monthly, yearly or only when necessary, e.g., in the case of an acute storm threat), the preferred communication channels (e.g., Internet, radio, newspaper, etc.) and the previous communication channels (if any). Respondents who answered 'no' to the question 'Would you like to know more about flood risks on the Belgian coast?' (which is part of the information need construct) had the possibility to explain why they do not want to receive such information (open question).

Results

Figure 6-5 shows the perceived usefulness of three information topics according to temporary and permanent residents. All three topics score high on the usefulness-scale, both by permanent and temporary residents. Information on evacuation procedures and escape routes scores highest on the 'very useful' category. When adding the 'useful' category, however, information regarding sea defence and actual safety level is clearly regarded as the most important compared to the other two topics (86.9% versus 73.8% and 77.0% for temporary residents; 84.2% versus 76.0% and 79.3% for permanent residents). Overall, 10 to 15% of the respondents takes the neutral category. Less than 10% doubts the usefulness of this information.

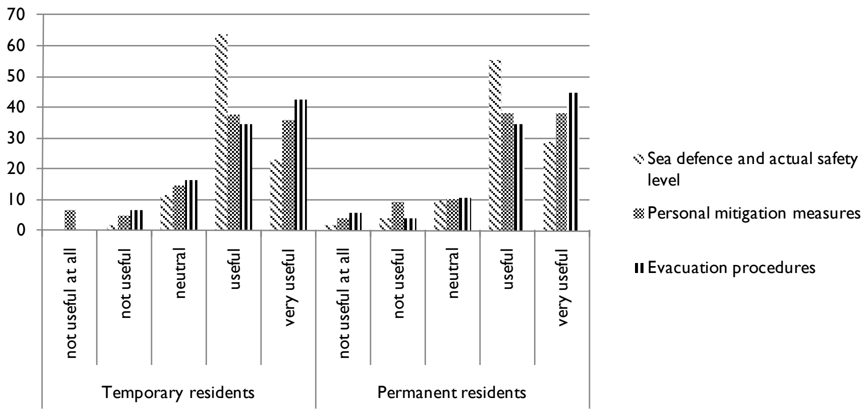

Figure 6-5 Perceived usefulness of risk-related information

Next, it is examined what the preferred information frequency should be: weekly, monthly, yearly or only when necessary, e.g., when a storm is imminent.

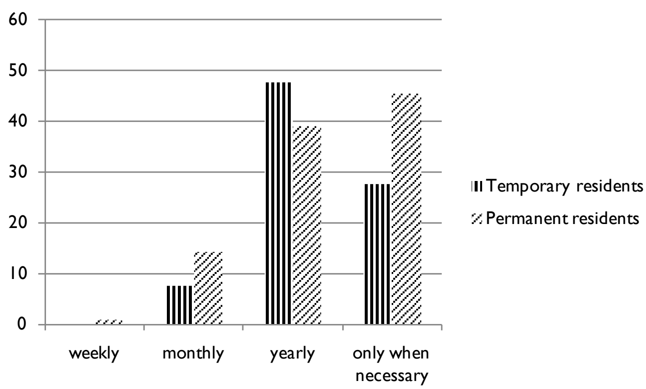

Figure 6-6 Preferred risk-related information frequency

Figure 6-6 shows that the majority of the respondents sees benefits in receiving risk-related information once a year or only when necessary. While most temporary residents (57.4%) opt for yearly communications, most permanent residents (45.6%) prefer communication only when necessary. In both groups, about one out of ten respondents prefers communication on a monthly basis. The choice for weekly communications is negligible.

Figure 6-7 depicts previously used and preferred communication channels for distributing coastal flood risk information. The graph clearly shows higher percentages of previous and preferred communication channels among the permanent residents, as compared to the temporary residents. The dissimilarities are most apparent for TV and neighborhood communication. There are further marked differences between previous and preferred communication channels, both among temporary and permanent residents. Almost all communication channels score notably higher on the preferred scale than on the previous scale. However, the top three of communication channels is slightly different between both scales. While TV, newspaper and Internet compose the top-3 among the previous channels, brochures are preferred above newspapers, both by temporary and permanent residents. It is further apparent that the top-3 sequence of preferred communication channels is just reversed between both groups of residents. The categories neighborhood and friends are clearly less functional for risk communication, though permanent residents would like to see more activities regarding risk communication in their neighborhood. Three extra categories are also worth mentioning here: (i) 'I don't know', (ii) 'Other' and (iii) 'Never'. While a negligible fraction of the respondents indicated that they had not any clue about risk communication channels, a relatively large number of respondents filled in 'other communication channels'. Among the diverse answers, 'magazines' were often mentioned, as well as 'the municipality', 'workshops', and 'by profession' (e.g., fishery). Noteworthy is that nearly 40% of the temporary residents had never received information on flood risks before. Among the permanent residents, less than 25% indicated the same.

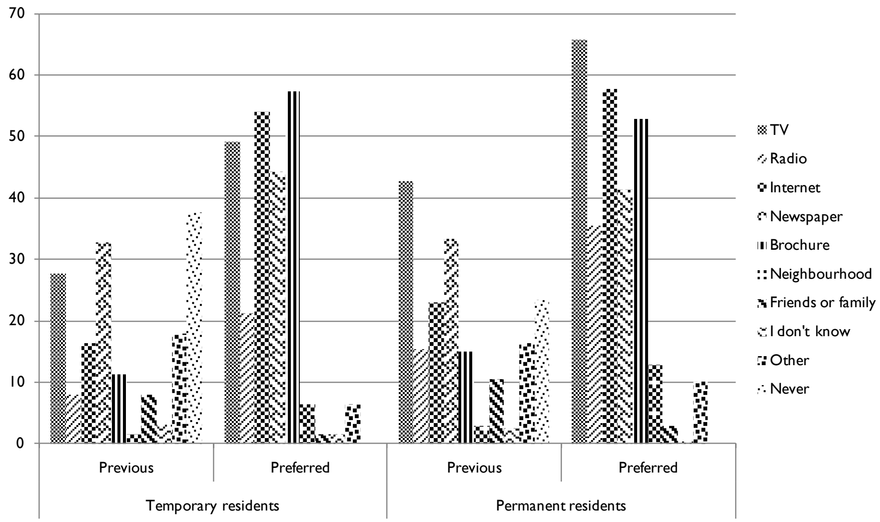

Figure 6-7 Previous and preferred communication channels for coastal flood risk information

Finally, it is examined why some respondents do not want to receive risk-related information (Figure 6-8). This group comprises four temporary residents (6.2%) and twenty-six permanent residents (10.4%). Except for one inhabitant, all answered the open question 'Why are you not interested in information about coastal flood risks?' Nine key reasons are distinguished: (i) low probability ('Risk is too small'), (ii) fatalism ('Nature is almighty, we cannot influence it'), (iii) avoiding panic ('Not necessary to spread panic'), (iv) trust in government and experts ('Municipalities are taking care of this problem'), (v) age ('I'm too old to be concerned'), (vi) disbelief ('I am living near the coast for 60 years now, and I have never encountered more nuisance than some overtopping waves along the dikes'), (vii) fear ('More information would frighten me'), (viii) sufficient knowledge ('I believe I know enough about the problem'), (ix) not important ('There are more important things that need to be handled first'). Figure 6-8 depicts these nine key reasons with their corresponding number of appearances in the respondent's answers. Despite the small sample group, it seems that flood hazard's low probability and the feeling of fatalism are the most 'popular' reasons to decline flood risk information.

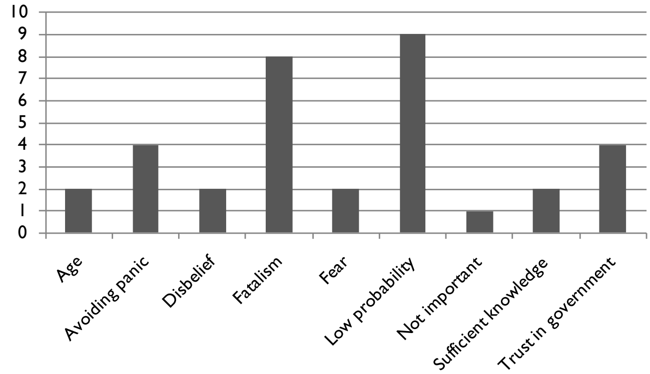

Figure 6-8 Key reasons for declining flood risk information

Discussion

The research objective in this addendum focused on the public's information need and its communication preferences. Three questions were examined: (i) *What* information is felt useful, (ii) *When* should this information be disseminated, and (iii) *How* should this information be disseminated?

Concerning the *what*-question, descriptive statistics revealed that the majority of the respondents (more than three quarters) finds *any* information on flood risk useful, whether it is general information on the sea defence or personal information on mitigation measures. Yet, on a closer look, it seems that general information is slightly more preferred, both by permanent and temporary residents. This is contrasting to previous research by Terpstra (2010), who emphasized the importance of communicating specific risk mitigating information to Dutch citizens. Although the context of our research is somewhat different, the fact that Belgian respondents rate general information that high might indicate a general shortage on flood risk communication. It seems that general questions – e.g., what is the actual risk and what does the government do about it? – first need to be handled, before communication on personal mitigation actions should be distributed.

Regarding the *when*-question, respondents slightly preferred frequent communication (weekly, monthly or annual) over acute notification (i.e. when a storm surge is expected). In contrast to what one might be expecting, particularly temporary residents demanded frequent risk information. This could indicate a certain resignation among permanent residents.

As regards the *how*-question, respondents were asked about the previously used and the preferred communication channels for distribution of coastal flood risk information. As expected from previous research (Kreibich *et al.*, 2009), TV and Internet scored high on the preferred scale, but surprisingly, brochures are rated higher than the 'classic' channels radio and newspaper, particularly among temporary residents. Our findings also support the use of brochures or leaflets in favor of neighborhood communication, which is contrasting to what previous studies have suggested (Terpstra *et al.*, 2009). The support for brochures might correspond to the finding that a majority of the respondents demands general information on actual flood risk and sea defence measures. Whereas neighborhood communication might be more useful for specific, person-based information, brochures and leaflets are more suitable to communicate general information.

Finally, it was investigated why a small number of respondents declined flood risk information in the future. Among their reasons, the flood hazard's low probability and the feeling of fatalism were cited most often. Flood risk communication could counter both arguments by addressing the 'low probability but high consequence'-issue and underline the fact that 'something can be done' to mitigate flood risks.

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7 GENERAL DISCUSSION

This chapter first recapitulates the research objectives of this dissertation and summarizes the main outcomes (Section 7.1). Next, critical reflections are given on diverse methodological aspects and avenues for further research are discussed (Section 7.2). Finally, implications and challenges for policy makers are presented (Section 7.3).

7.1 Summary

This dissertation has been prompted by several trends and developments in flood risk management. First, it addresses the growing attention to the public flood risk perception (*subjective* risk assessment) and the increasing demand for research on flood risk communication. Second, it deals with the increased flood risk in coastal areas, a trend that is mainly triggered by climate change effects (in particular sea level rise and storm frequency) and urbanization (economic development, demographic pressure, tourism, etc.). Third, it focuses on the Belgian coast since this region is on the verge of realizing new defence measures to improve its protection against flooding.

Three research objectives were addressed in this dissertation.

> *Objective A: To review the state of the art in research on objective (i.e., technical) and subjective (i.e., perceived) flood risk assessment (RQ 1 and RQ 3).*
>
> *Objective B: To analyze particular research gaps in objective and subjective flood risk assessment in coastal areas (RQ 2 and RQ 4).*
>
> *Objective C: To suggest elements to improve flood risk communication in coastal areas (RQ 5).*

Five research questions (RQ) were distilled from the above research objectives, each of which were tackled in a chapter of this dissertation.

RQ 1: What is the state of the art in flood risk management in Flanders and what are the future challenges?

In recent years, Flanders (the northern part of Belgium) has substantially improved its flood management. Its shift from a flood control approach –

which serves protection against a certain water level – to a risk-based approach – which serves protection against losses while taking the probability of occurrence into account – has clearly proven a necessary one (Broekx *et al.*, 2011). While the former approach resulted in perennial heightening of dikes and levees, the latter focuses on the potential environmental impact of a flood event (Merz *et al.*, 2010). Since these technical flood risk analyses (cf. *objective* risk assessment) enable identifying vulnerable areas, they have been rapidly embraced by policy makers concerned about flood impact minimization (e.g., by choosing the best mitigation measures). Major strength of the risk-based approach is the possibility to compare risks over time at the same location (e.g., historic study of flood risk evolution in a basin), between scenarios at the same location (e.g., impact study on the construction of pumps) or between locations at the same time (e.g., identifying the most vulnerable areas for a given flood event) (Vanneuville *et al.*, 2006).

Through a review of the risk methodology, Chapter 2 showed that Flanders currently focuses on the assessment of direct, economic damage and human casualties. Partly due to its small area, Flanders has succeeded to calculate flood risk maps of all major river basins and the coastal area in a uniform way and at a high resolution (5 x 5 m^2 grid). By two case studies, Chapter 2 further demonstrated the working of the risk methodology in two different locations (river versus coast) from a different research angle. Whereas the first case study examined the impact of planned infrastructure works on the Yser (i.e., comparing risks between scenarios), the second dealt with coastal flood risks on the Belgian coast (i.e., identifying the most vulnerable areas). By testing different data sources at the same time (i.e., temporal variation in agriculture, more detailed land use), the first case study particularly showed the value of relative risk calculations. While absolute risk values greatly depend on the data that is employed, relative values (percentages) are more persistent and more reliable to judge risks. The risk calculations in the second case study showed that especially Oostende is a vulnerable place towards coastal flooding, both in terms of economic damage and human casualties.

Although Flanders ranks among the best European regions regarding its flood risk assessment, a number of improvements and challenges remain for the future. Possible improvements deal with the assessment of indirect, external economic damage (e.g., production losses outside the flooded area) and the inclusion of population dynamics in casualty calculations (cf. Chapter 3). The coming into force of the European Floods Directive (FD) in 2007 has generated additional challenges for the Flemish flood risk management.

Among the most cited are the quantification of intangible effects of flood hazards (e.g., health effects) and the inclusion of other than river and sea-borne types of floods. While the FD promotes *passive* communication of flood risks (i.e., risk management plans should be 'available' to the public), many researchers plead to go one step further by organizing *active* flood risk communication (Mostert and Junier, 2009). Knowledge of the public perception is regarded a vital factor to develop effective risk communication (cf. Chapters 5 and 6).

RQ 2: To what extent is coastal tourism an important factor in flood risk management of coastal areas?

While Chapter 2 showed that risk calculations are elaborate in Flanders, one particular aspect had long been overlooked on the Belgian coast, namely the presence of temporary residents or tourists. Coastal tourism is regarded as one of the fastest growing areas of the tourism's industry (Hall, 2001). As far as flood risks are concerned, coastal tourism can greatly influence the number of people exposed to such hazards (Jonkman, 2007). In addition, tourists are deemed more vulnerable to flood disasters than locals, since they are less independent and less familiar with the environment and its characteristics (Burby and Wagner, 1996; Faulkner, 2001). In Chapter 3, it was examined whether the inclusion of tourism dynamics is meaningful and feasible in coastal flood risk management. Detailed tourist census data were therefore applied, containing the daily occupancy rate of the second residences on the Belgian coast for the period June 2007 – May 2008. Survey data was additionally employed to assess the behaviour of tourists in 'extreme' weather conditions (i.e., stormy weather with high wind speed and overflowing water along the dikes). In accordance to previously reported storm behaviour of people (Cantillon *et al.*, 1999), it was found that residential tourists are rather persistent in their holiday plans, irrespective of storm forecasting.

Based on these outcomes, it seemed relevant to consider the presence of tourists (or at least the majority of tourists) during severe storm conditions. Statistical analyses on the tourist census data subsequently showed clear seasonal fluctuations, as well as day-to-day differences due to weekend days and holidays. Average tourist numbers for the summer and winter half year served as input for the risk analysis in GIS, as well as a worst-case flood scenario (CLIMAR WCS 2040). While such a flood would affect large parts of the coast, the outcome of the analysis showed that particular attention should be given to locations of which the risks increase significantly when considering temporary residents. Hence, municipalities such as De Panne and De Haan were found vulnerable touristic places. Overall, inclusion of tourism dynamics increased the expected casualty number with 37% during Summer half year, and with 18% during Winter half year.

The question as to what extent tourism dynamics may influence risk management is difficult and depends on the study area, the pursued objectives and data availability. The implications for a touristic area like the Belgian coast have been shown, although data restrictions limited the analysis. More detailed data (e.g., varying occupancy rate of second residences at the level of the municipality instead of the entire coast) would enhance the study, as well as more accurate information regarding the probability of a summer versus winter storm.

Yet, regardless of data restrictions, Chapter 3 revealed a vulnerability of coastal tourists which constitutes at three levels: spatial (majority of tourists reside on or near the coastline), temporal (tourism is susceptible to large temporal fluctuations) and behavioural (tourism behaviour is difficult to predict). Above all, Chapter 3 showed that, as far as the Belgian coast is considered, residential tourists should not be overlooked in flood risk management. Generalizations to other coastal and non-coastal areas (e.g., touristic mountainous areas) could be made, though with the proper circumspection.

RQ 3: What is the state of the art in flood risk perception and flood risk communication research? Which methodologies are employed and what are the main findings and shortcomings in these research fields?

It is becoming widely acknowledged that flood risk management is shifting from a primarily *objective* approach to an integrated approach with attention to social – *subjective* – aspects such as improving flood preparedness and response (Terpstra and Gutteling, 2008). These subjective aspects exhibit the main focus of flood risk perception research, a relatively new study field which interferes heavily with flood risk communication.

While previous articles have reviewed general aspects of risk perception and risk communication (e.g., Fischhoff, 1995; Boholm, 1998; Bier, 2001), a comprehensive review article of risk perception and risk communication in flood risk research was still missing. Chapter 4 addressed this literature gap by presenting an extensive review of empirically based peer-reviewed articles on flood risk perception and communication. To this end, a carefully considered search key was conducted on Web of Science and Scopus databases, which resulted in a set of 57 articles from 22 different countries.

A closer look to these articles revealed that most studies were produced in Europe and North America, and that 85% of the studies had been published after 2005. Research in the study fields of flood risk perception and flood risk communication is clearly growing. Further analysis on the methodologies and theories applied showed that the majority of the studies refrained from using a formal theory. Most studies in risk perception have an exploratory objective, which results in heterogeneous approaches and methods and makes outcomes from different studies difficult to compare. Chapter 4 suggested three steps to tackle this issue. First, research should consider theoretical constructs that are useful to measure flood risk perceptions. Second, the operationalization of these theoretical constructs could be improved by copying or at least by reflecting on previously used questionnaire items. Third, authors should report all relevant information regarding questionnaire items: reliability, means, standard deviations, and correlations. Regarding flood risk communication, theoretical and empirical research was found to be almost nonexistent. While several studies provide recommendations towards communication experts, most of these recommendations are indefinite, and consequently difficult to put into practice. Very few studies have explicitly focused on the effects of flood risk communication (Terpstra *et al.*, 2009) or the theoretical background behind information need and seeking intentions (Griffin *et al.*, 1999).

RQ 4: Which factors determine the public's flood risk perception in coastal areas? Does subjective risk assessment correspond to objective risk assessment and how is the geographic location linked to someone's perception?

It is widely held that flood risks will increase significantly in the 21st century in many coastal areas worldwide, as a result of sea level rise and economic developments (Dolan and Walker, 2006). Similar expectations are true for the Belgian coast (Lebbe *et al.*, 2008). While several projects (e.g., Master Plan for Coastal Safety, CLIMAR) have extensively studied objective risk assessments on the Belgian coast, the public perception and opinion remain highly underexplored (Mertens *et al.*, 2008).

Chapter 5 filled this research gap through an extensive survey, in which inhabitants and residential tourists from three municipalities (Oostende, Knokke-Heist and De Panne) were asked about their opinions and viewpoints on various aspects of coastal flood risks. In addition, a variety of personal and residential factors were measured, as well as location, which was – according to technical risk assessments – divided into a high and a low risk area (respectively Oostende versus Knokke-Heist and De Panne). In response to the suggested steps of Chapter 4, risk perception was measured via scaled items that were adopted from previous research (Terpstra *et al.*, 2006). Multiple regression analysis was employed to test five hypotheses, which were deducted from the literature on the perception of natural hazards in general and flood risks in particular. In sum, the analysis revealed consistency between the expert's risk estimates and the public's risk assessment, suggesting that the differences between expert and lay people might be smaller than often reported (Rowe and Wright, 2001; Wright *et al.*, 2002). Conform previous research (Lindell and Hwang, 2008; Ho *et al.*, 2008), significant positive effects were found for age and female gender. Against the expectations, owning a house (instead of renting) or residing permanently on the coast (instead of temporary) did not influence risk perception significantly, neither did the residential characteristics sea view, having a cellar or residing on the ground floor.

The effect of geographic location (municipality) was found to be partly mediated by flood experience, though other – un-measured – processes may influence this relation more strongly, such as public works to coastal defences (beach nourishment).

Finally, a marginal evidence was found for a *levee effect* among inhabitants, an effect that refers to a false sense of safety of people living behind water defence structures (Tobin, 1995). While it was expected that permanent residents (inhabitants) from Oostende would exhibit the highest levels of perceived risk, temporary residents (tourists) visiting Oostende were found to have the highest risk perception. However, outcomes in Chapter 6 convincingly countered this result. Indeed, in this study strong significant effects were measured between residing permanently on the coast and having higher levels of flood risk perception. While this outcome supports the findings of recent studies in the field (Burningham *et al.*, 2008; Lindell and Hwang, 2008), it is worth scrutinizing the contradiction between Chapter 5 and 6. One reason might be the time lag of two years between the two studies. It seems plausible that the recent infrastructure works and media attention on the Belgian coast have particularly affected the permanent residents and consequently have raised their risk perception levels. A second reason might be related to the different sample characteristics of the two studies. Whereas the group of temporary residents contained both residential tourists and second residence owners in Chapter 5, specific attention was given to second residence owners in Chapter 6. Comparing the outcomes of both chapters at this detail level is therefore delicate.

RQ 5: How can the knowledge of risk perception be informative to communication experts and what are the preferences and needs of the public towards flood risk communication?

Knowledge of the public's risk perception is deemed essential to outline effective risk communication strategies (Keller *et al.*, 2006; Bell and Tobin, 2007). After all, one can only adjust information to the specific needs of the people if he knows what these needs are (Renn, 2006). But what determines people's need for information, and what motivates people to seek for information? Information seeking models such as Griffin's Risk Information Seeking and Processing model (RISP; Griffin *et al.*, 1999), the Framework for Risk Information and Seeking (FRIS; ter Huurne and Gutteling, 2008) and the Planned Risk Information Seeking Model (PRISM; Kahlor, 2010) have addressed these questions. Stemming from the Heuristic-Systematic Model (HSM; Eagly and Chaiken, 1993) and the Theory of Planned Behaviour (TPB; Azjen, 1991), these communication models aim at identifying various factors that stimulate people to seek for risk information, leading to better risk-avoiding behaviour. They regard information *in*sufficiency (or information need) as the key factor that motivates people to seek for and process risk-related information, though several other factors (including risk perception) have been proposed and tested, as well as their interrelations. However, little empirical support exists of these models. In addition, the complexity of these models hinders clear mediation analyses (Kahlor, 2010).

In response to this, Chapter 6 examind the relationships between information seeking behaviour and its main determinants in the context of coastal flood risks. Particular attention was given to the often suggested mediating relationship of information need and to the effects of residing permanently in a flood-prone area or not. Data was collected through an on-line questionnaire in the city of Oostende, which was found a vulnerable location on the Belgian coast in previous chapters (cf. 2, 3 and 5). In support of previous research

(Kievik and Gutteling, 2011), path analysis revealed significant direct effects of information efficacy on seeking behaviour, which signified people exhibit stronger seeking intentions if they believe the information is useful to them. The analysis further showed that permanent and older residents tend to have stronger intentions to seek for risk-related information than temporary and younger residents. In contrast to the models of Griffin *et al.* (2008) and ter Huurne and Gutteling (2008), yet in support of Kahlor (2010), no mediating effects were found for information need on seeking behaviour. This outcome signaled the importance of investigating in active flood risk communication, since high information need levels among the public (92%) are not necessarily the herald of increased seeking behaviour. Full mediation effects of risk perception and perceived hazard knowledge between permanent residence and information seeking behaviour further indicated that communication campaigns should focus on raising awareness and knowledge about coastal flood risks, giving specific attention to temporary residents.

Among other findings, a supplementary descriptive analysis (Addendum, Chapter 6) revealed that both general and specific (personal) risk information is appreciated, which again point to a general shortage in flood risk information (Visschers *et al.*, 2007).

7.2 Critical reflections and avenues for further research

While a specific discussion is provided after each chapter (except for Chapters 1 and 2), this section aims at discussing a number of general and covering aspects of the dissertation, ranging from collecting data and examining mediation and causality to the value of qualitative research and the difficulty of integrating objective and subjective risk assessment. Avenues for further research are discussed where appropriate.

7.2.1 Data collection

Collecting data is a crucial aspect of research. In this dissertation, different types of data have been used. Here, we discuss some general problems regarding data collection that were encountered in this dissertation.

In Chapters 2 and 3 (focus on technical, objective risk assessment), it was a matter to bring together various data sets, such as land use maps, socio-economic data, flood maps, etc. Geographic information systems were used to calculate economic and casualty data risks. While in Chapter 2, risk analyses were performed on existing data layers (collected by Flanders Hydraulics Research), in Chapter 3 external data was added to the risk calculations (i.e., occupation rates of second residences and tourist numbers; personally collected survey data). It should be underlined that technical risk assessments are principally subject to data restrictions (Apel *et al.*, 2009; Merz *et al.*, 2010). Developments in the risk methodology are therefore data driven, which means that new data generally produces refinements or extensions to the methodology. The availability of tourist-related information allowed the examination of this particular aspect of coastal flood risks. However, more detailed information on tourist numbers (both in terms of space and time) would possibly result in even better insights in the relation between tourism dynamics and risk calculations. Mobile positioning data (obtained via GPS and mobile phones) might be promising in this regard (Ahas *et al.*, 2008). Data restrictions also account for the difficulty to consider intangible effects of flood risks (e.g., health effects, loss of cultural heritage, etc.) which is demanded by the European Floods Directive (Mostert and Junier, 2009).

The study of social – subjective – risk assessment in Chapters 5 and 6 implied individual data which is preferably collected through surveys. Bird (2009) distinguished a multitude of survey types, depending on the approach (quantitative, qualitative, mixed-method), types of questions (classification, behavioural, knowledge, perception and feeling, the mode of distribution (self-administered, such as mail and email, or administered, such as telephone and face-to-face interviews) and the sampling technique (probability or non-probability). Choosing the best survey type mainly depends on the research question. In our research, it was intended to analyse quantitative data from a large sample in order to get significant generalizable results. Self-administered surveys, such as mail questionnaires are appropriate in this regard (Lindell and Perry, 2000).

However, a number of methodological issues may threaten the validity of survey results. Here we discuss target population, non-response and sample representativeness. As mentioned before, the target population in this dissertation was not limited to inhabitants of the coastal area, but also included temporary residents and tourists who have spent at least one night on the Belgian coast (residential tourists). While the distribution method of random post-boxes seemed appropriate to reach inhabitants and temporary residents who own a dwelling on the Belgian coast (second homeowners), it was less suited to attain those tourists who rent their dwellings for short periods, since they generally have no access to post-boxes (and even if they had access, most tourists would not expect to receive post). This issue of reaching ‘real’ tourists (those who rent) was partly tackled in the first survey (cf. Chapter 5) by handing out questionnaires to people in the street. In this regard, face-to-face interviews or focus groups could have been more efficient to reach this particular group. Then again, these intensive survey methods are more suited for retrieving qualitative information. We will revisit this issue further in this section.

A second issue concerns non-response. People who did not fill in the questionnaire may had informative reasons not to do so (Grothmann and Reusswig, 2006). It is very difficult to consider this group. Other survey types such as face-to-face interviews could reduce this bias, since the interviewer can probe into the reason behind the respondent’s decline. Lindell and Perry (2000) have discussed this issue in the framework of people’s perceptions towards earthquake hazards. They reported that non-response might make the sample’s representativeness uncertain, particularly in samples with low response rates. While the mail questionnaire (cf. Chapter 5) resulted in a moderate response rate of 20.6 %, the on-line questionnaire (cf. Chapter 6) yielded a low response percentage of 6.3 %. Although Internet penetration is increasing in Belgium (67 % in 2010), it still seems insufficient to attain a large response rate. Reminders could have increased the response, though their effect is often limited (Terpstra, 2010).

In addition, evaluating the sample representativeness constitutes a difficult job, since actual data of the target population is often not available. For instance, no detailed information was available to test the representativeness of the temporary residents (tourists). Based on tourism data (Gunst *et al.*, 2008), the ratio of permanent and temporary residents seemed to match the real situation. The representativeness of other variables (e.g., age, gender, education) could be tested using the data of the Socio-Economic Survey (SEE2001). As far as the group of inhabitants is concerned, the samples of both surveys were slightly biased toward older men and high-educated people. As Terpstra (2010) indicates, such biases may result in only small net effects in the statistical analyses if the sampled groups are equally biased. The samples in Chapters 5 and 6 seem to fall under this statement.

7.2.2 Mediation and causality

The literature review in Chapter 4 showed that mediation analyses are important to understand the relations between variables and to advance theories. A mediation model is one that attempts to identify and elucidate the mechanism that underlies an observed relationship between an independent variable and a dependent variable via the inclusion of a third explanatory variable, known as a mediator variable (Baron and Kenny, 1986).

Chapters 5 and 6 both tested mediating relationships. In Chapter 5, a multiple mediation model was proposed with location as independent variable, risk perception as dependent variable and personal experience with storm surges and/or (coastal) floods as mediator variable. In Chapter 6, single mediation was employed with information need as mediator variable between information seeking behaviour and risk perception and between information seeking behaviour and perceived hazard knowledge. In addition, multiple mediation was examined with risk perception, perceived hazard knowledge and information need as mediators between individual characteristics and information seeking behaviour. The combination of this single and multiple mediation led to a sequential mediation model (MacKinnon *et al.*, 2002).

In response to the different mediation complexity in Chapters 5 and 6, two different analysis methods were employed. In Chapter 5, bootstrapping was performed through the use of an SPSS macro, which is developed by Preacher and Hayes (2008) and is available on the internet free of charge ('indirect.sps' at www.afhayes.com). Bootstrapping is a relatively new but promising method in social science research. Through extensive sets of simulations, MacKinnon *et al.* (2002) showed that bootstrapping performs better than other popular methods, such as the Sobel test (Sobel, 1982) or the causal steps approach (Baron and Kenny, 1986), on the grounds that the former has higher power while maintaining reasonable control over the Type I error rate. In addition, bootstrapping does not impose the assumption of normality of the sampling distribution, which makes the method extremely useful for smaller samples as well. Chapter 5 showed that bootstrapping is an attractive method for future research in perception research and social science.

However, the complex sequential mediation model in Chapter 6 demanded the use of other techniques than bootstrapping. Previous studies in flood risk research have mainly employed Structural Equation Modelling (SEM) software such as LISREL (Griffin *et al.*, 2004; Zaalberg *et al.*, 2009) and AMOS (ter Huurne and Gutteling, 2008; Kahlor, 2010; Trumbo, 2002) to unravel such relationships. Because of their greater flexibility in model specification and estimation options, Preacher and Hayes (2008) recommend to use Structural Equation Modelling (SEM) to estimate mediation models. SEM explicitly models measurement error, which enables the testing of hypotheses using latent (i.e., unmeasured) constructs rather than imperfect measured variables. A major disadvantage of SEM is that it demands very large samples to work properly (Kline, 2005). Chapter 6 met this issue by identifying latent variables (e.g., risk perception, information seeking behaviour) through a preliminary factor analysis in SPSS, followed by a path analysis using LISREL in combination with PRELIS (for correlations and standard deviation matrices). Although this approach is widely accepted, it might definitely be interesting for future research to perform full SEM on larger samples (of 1,000 cases and more).

While mediation models are a consistent approach to reveal direct and indirect effects between variables, a specific issue concerns the impossibility of testing causality. However, this issue is mainly caused by the use of cross-sectional data (i.e., data collected by observing many subjects – such as individuals – at the same point of time). Establishing causality requires evidence of temporal ordering (i.e., whether, if two variables are correlated, A caused B or vice versa), which is impossible to identify with cross-sectional data (Lindell and Hwang, 2008). As denoted in Chapter 4, a solution to this would be to employ an experimental or longitudinal design, in which data is collected at multiple points in time. Such research designs are very useful to examine the effects of risk communication and evaluate various communication formats and strategies (Terpstra *et al.*, 2009).

7.2.3 Value of qualitative research

Since Fischhoff and Slovic introduced risk perception as a quantifiable concept in their psychometric paradigm (Fischhoff *et al.*, 1978; Slovic, 1987), quantitative studies have emerged rapidly in the study field at the expense of qualitative methods. While both methods have their strengths, quantitative methods are now clearly the most popular in risk perception research (e.g., Grothmann and Reusswig, 2006; Siegrist and Gutscher, 2008; Terpstra *et al.*, 2009; Zaalberg *et al.*, 2009). Quantitative data is appropriate to reveal general trends, uncover correlations and perform significance tests. However, quantitative data contains limited context information, which makes it difficult to interpret it at the individual level. The strength of qualitative research is the possibility to explore individual preferences and opinions with as much context as needed. As such, qualitative data permits to grasp the various factors that influence a vague construct such as risk perception (Trumbo, 2002).

While the surveys in this dissertation mainly collected quantitative information, qualitative information has also been gathered through the use of several *open* questions. In Chapter 6, for example, open questions were used to uncover the reasons why people declined future flood risk information. In the first survey (Chapter 5), respondents had the opportunity to freely write down any of their concerns regarding all possible aspects of coastal defence, flood risks, the management, or the perception research itself. About 22% of the respondents took the opportunity to ventilate their concerns and viewpoints. It was apparent that the storm surge of 1953 was mentioned quite often, while there was absolutely no reference to this event in the questionnaire. A 77-year-old man described:

> *'We have had enormous experience with the flood in Oostende [1953]. We were in the middle of it, we lived near the dike [...]. Horrible. We will never forget that.'*
>
> *'Before 1953, the [sea]water reached the houses on a regular basis. The hall and cellar got frequently flooded. I have canoed on the market [of Oostende]! My car was flooded.'* (female, 84 years old)

Obviously, such qualitative information is not appropriate to generalize nor to make conclusions for the entire population. Yet, they clearly provide extra context-related information to the findings of the quantitative analyses. In this case, they show the relevance of the storm surge of 1953 as a significant event that lasts as a strong memory among many (older) individuals. Other comments of respondents concerned the coastal defence, and particularly the technique of beach nourishment (also referred to as beach feeding or beach recharging).

> *'It seems to me that beach nourishment is a temporary solution, which needs to be repeated too often.'* (female, 51 years old)
>
> *'It is no use to rely on beach nourishment; the recharge material is already disappeared after one severe storm.'* (female, 60 years old)

These comments on the usefulness of beach nourishment provide a valuable background, since they prove a certain overestimation of knowledge. People *think* they know what the technique is, though their answer shows the opposite. Quantitative analysis alone cannot reveal such information.

Finally, a group of comments concerned the vulnerability of cellars. Although it was not asked specifically in the questionnaire, two respondents expressed their concern about the flooding of (non-)private cellars:

> *'The biggest risk is located in the cellars of the flats. Cellars often contain electricity supplies, which also run the heating system…'* (male, 54 years old)
>
> *'After the floods of 1953 we had left our apartment at the park [located in the centre of Oostende], and began to build a new flat on the explicit condition that no cellar would be installed.'* (male, 72 years old)

Thus, while quantitative analyses revealed no significant results for factors of cellar possession (cf. Chapter 5), some people do recognize the problem of having a cellar.

The above citations are not intended to provide a complete discussion on the qualitative outcomes of our surveys, but rather they demonstrate the additional information that can be obtained from such information. Instead of mail questionnaires, qualitative data would be preferably collected through other survey methods such as interview or focus groups. Analysis techniques such as content analysis would then be appropriate to deduct information from the data (Driedger, 2007). Since quantitative and qualitative both have their strengths and weaknesses, several researchers have suggested to employ a mixed-method approach which combines the best of both worlds (Kwan and Ding, 2008). Such a mixed-method approach might therefore be a promising technique for future research in the field.

7.2.4 Integrating objective and subjective risk assessment

While objective and subjective risk assessments of coastal flood risks were the focus of this dissertation, an integration of both approaches has not been discussed so far.

Let us first consider what is understood by 'integration'. As denoted in the Introduction of this dissertation (cf. p. 8), an integrated approach should strive to bring together the opinion and viewpoints of experts and decision-makers, as well as local stakeholders and the public (Brilly and Polic, 2005). Renn (2004) stated that 'what is really needed is mutual enhancement between technical risk assessment and intuitive risk perception. Risk policy should neither be purely science-based nor purely value-based.' The integration of opinions and viewpoints should preferably be realized in both directions, since experts and lay people can learn from each other (Kaiser *et al.*, 2004; Renn, 2005). Hence, the end goals of such integrated approach are public participation and stakeholder involvement (Renn, 1998).

However, integrating experts' estimations and lay people's perceptions is certainly not a piece of cake. Several difficulties have been identified and described in previous research. Figueiredo *et al.* (2009), for example, describes issues regarding language and beliefs. The language used by specialists differs substantially from that of the lay public. Whereas specialists base their risk assessment and management on the quantification of probabilities and consequences, the general public employs a wide range of factors resulting from presupposition and subjective approaches. Controversy arises since neither the messages from specialists to the public, nor the messages from the public to the specialists are fully understood. In addition, technicians and scientists often have the belief that the public is void of practical value in the risk analysis and decision-making (Bickerstaff, 2004). Klinke and Renn (2002) reported that many technical experts contend the inclusion of lay perspectives in risk management, since public perceptions are susceptible to sensational press coverage and intuitive biases. They further stated that 'ignorance or misperceptions should not govern the priorities of risk management'.

Apart from the difficulties in integrating objective and subjective approaches, public participation is not a panacea, nor is stakeholder involvement. Milligan *et al.* (2009) describes a number of pitfalls, such as involving multiple viewpoints without focussing too much on individual and personal biases. Hence, it is extremely difficult to balance the interests of multiple stakeholders. In addition, it might be a challenge to find the appropriate stakeholders and not excluding important ones. Fletcher (2003) from his side states that public participation or stakeholder involvement might undermine representative democracy and lengthen proceedings beyond the time scale of funding.

Despite the difficulties and pitfalls, many researchers recognize the potential of participation programs to enhance the relationships between the different parties. It will obviously be a key challenge for future research to scrutinize the usefulness of such approaches and to realize a profound entwining of the diverse opinions, desires and viewpoints from the experts and the various stakeholders.

7.3 Policy implications and challenges

The study and management of flood risk is a topical subject in Flanders. Previous flood hazards in river catchments have strengthened the understanding among policy makers that risk mitigating measures are essential. With respect to the Belgian coast, recent projects have demonstrated weaknesses of the coastal defence against a major storm surge. The expected developments of the sea level rise and the urbanization rate are regarded to further increase coastal flood risks, if no action is undertaken in the future. While policy makers seem to realize the necessity to investigate in an improved coastal defence, an important stakeholder remains underexposed in this story: the public. Yet, policy can only rely on public support if the population is sufficiently informed about the rationale of the choices that are being made (Mertens *et al.*, 2008). Hence, public awareness and understanding is indispensable to consolidate technical measures (e.g., raising dunes, constructing new seawalls, completing beach nourishments, etc.). While the EU Floods Directive imposes the member states to produce flood risk management plans and to make them available to the public, commitments regarding active flood risk communication and public participation are still lacking. Recent European projects, such as COMRISK and SafeCoast have underlined the importance of communicating flood risks. The on-going CRUE-ERA NET funding initiative stimulates research towards social aspects of flood hazards, such as risk perception, awareness, resilience and vulnerability (www.crue-eranet.net). To date, however, policy makers have not yet been moved to implement stringent regulations or obligations in this regard.

This dissertation clearly demonstrated a general request among the residents of the Belgian coast for being informed about coastal flood risks and how they are managed. Whereas the study in Chapter 6 focused on the residents from Oostende, the on-line survey was available to permanent and temporary residents from the entire Belgian coast.[7] Descriptive analysis on the complete sample ($N = 826$) revealed high percentages of information need in other

[7] The survey method (on-line questionnaire) allowed everyone who was interested in the research to fill out the questionnaire. The survey was made knowable in other coastal municipalities through their websites and digital newsletters.

coastal municipalities as well (approximately 90%). Hence, it seems justified to say that the majority of the coastal population is demanding party for more information on coastal flood risks.

Despite the public's interest in flood risk information, policy makers will face a number of challenges to successfully communicate about these risks. It is worthwhile to deepen three major challenges here: (i) the content of the message, (ii) the message channel, and (iii) the audience. The first challenge deals with the risk message. Which information should be sent to the citizen: general information or specific (local) information? From Chapter 6, it seems that the public is interested in *any* kind of information, whether general (e.g., actual safety level, consequences of coastal flood hazards) or specific information (e.g., information on personal measures, instructions regarding evacuation, etc.). It has been discussed previously that this could point to a general shortage in flood risk information. Yet, this certainly does not mean that *any* kind of information is usable to communicate about flood risks. Wrong-stated information might lead to misconceptions which consequently might upset or even frighten people (Visschers *et al.*, 2009).

The second challenge refers to the channels of risk communication. Whereas previously TV and newspapers were the prominent channels for risk-related information, Internet is becoming more and more assigned as the most important source of information in the future, next to TV and brochures. However, as Smith and Petley (2009) acknowledge, the growth of on-line sources of information has complicated matters further. Smith and Petley particularly question the quality of the information available on the Internet, which may reinforce misconceptions. Furthermore, the Internet demands active information seeking behaviour of the public, whereas TV and brochures are 'passive' sources for information dissemination. Then again, the Internet allows bidirectional communication (e.g., through interactive websites), which has been widely acknowledged to be more effective than one-way communication (Höppner *et al.*, 2010). In Belgium, information regarding coastal safety is currently available on the Internet via the website of the Agency for Maritime and Coastal Services, though it concerns several expert reports which are difficult to read by the public. A website, specifically designed for information dissemination regarding coastal safety, with clear texts and illustrative figures and animations, is still lacking.

Finally, the third challenge deals with the heterogeneity of the audience. In this regard, Chapter 5 revealed that risk perception differs according to age, gender, and previous flood experiences. According to the theory, the knowledge of the public's risk perception allows adjusting information dissemination to the needs and the preferences of the public (Renn, 2005; Keller *et al.*, 2006). In practice, however, it is impossible to meet everyone's needs, since one should then communicate at the individual level. Nevertheless, at an aggregated level, the knowledge of risk perception provides elements that are useful to develop more effective communication strategies. For instance, communication experts should explicitly distinguish between the concerns of the elderly and the interest of the young adults. Historical material, such as the 1953 storm surge, may stimulate (forgotten) experiences among the elderly and may trigger risk awareness among the younger people. Obviously, a clear sketch of the circumstances would be imperative in such case, since the context has been changed drastically since then. Therefore, simulations under present or future conditions could be very effective (Zaalberg *et al.*, 2009). An additional challenge concerns risk communication to temporary residents of the Belgian coast. Although they express similar interests for being informed about coastal safety, they are much more difficult to reach. Moreover, it will be highly delicate to inform this group in a way that advances risk management without harming the interests of the tourism industry on the Belgian coast.

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8 GENERAL CONCLUSION

Worldwide, coastal flood risks are receiving increasing attention. Recent hazards, such as hurricane Katrina (New Orleans, 2005), cyclone Sidr (Bangladesh, 2007) and storm Xynthia (French coast, 2010) have demonstrated the fateful potential of coastal floods. Expectations regarding climate change (sea level rise) and economic development (coastal urbanization) further underline the need to study these risks.

While flood risks have been predominantly approached from a technical, objective perspective, recent years have witnessed a growing concern to consider subjective aspects of these risks as well. This dissertation examined both approaches through literature reviews and analyses. Study area throughout the research was the Belgian coast, which is on the verge of improving its defence structures to assure protection against future storm surges.

Through application of geographic information systems, it was firstly shown that flood risks on the Belgian coast are not negligible, neither in terms of damage, nor in terms of human casualties. Profound analysis on tourism dynamics and tourist behaviour further showed that current casualty risks may be significantly underestimated. Tourists are considered to be particularly vulnerable to storm surges since they generally reside closer to the coastline than inhabitants, fluctuate in numbers according to season and holidays and are less familiar with the context of coastal defence and flood risks. Based on these outcomes, residential tourists were explicitly considered in the remainder of the dissertation, together with coastal inhabitants. In this part of the thesis, attention was given to the public perception and communication of coastal flood risks. To this end, two extensive surveys were organized on the Belgian coast. The first survey probed into the inhabitant's and tourist's perception of coastal flood risks at three locations: Oostende and Knokke-Heist and De Panne. Through regression and mediation analysis, the level of perceived risk tended to be higher for older respondents, women, and people with flood experience. The second survey focused on the public's preferences, needs and behaviour regarding flood risk information. Path analysis was employed to test relationships between various predictors of information seeking behaviour. Previous information seeking models provided the framework for these analyses. The analysis showed that risk perception and perceived hazard knowledge are higher for permanent than temporary residents, leading to increased information seeking behaviour among the former group. In addition, descriptive analysis showed that an overwhelming majority of the respondents is demanding party for receiving more information on coastal flood risks. General information at regular time intervals was preferred most, although specific information regarding personal measures and evacuation procedures would also interest many people. Regarding communication channel, the Internet, television and brochures were preferred to radio, newspapers and neighbourhood meetings.

In sum, this dissertation bundles research that methodologically and empirically contributes to the analysis, perception and communication of coastal flood risks. Geographic information systems were applied to conduct *objective* risk assessments, whereas regression and path analyses were found appropriate to examine *subjective* risk assessments. Different data sets were employed, from tourism data (WES, research and consultancy office of West-Flanders) to various survey data regarding tourist behaviour, risk perception, information need, etc. This dissertation demonstrated that the study of people's perspective on flood risks is useful to anticipate the public's preferences, needs and concerns and that more attention should be given to subjective risk assessment in flood risk management. Moreover, the findings in this thesis suggest there is public support for more risk communication in coastal areas. Although most people do not often give flood risks on the Belgian coast a moment of thought, a majority recognizes the fateful potential of a storm surge.

These findings suggest that policy makers should legitimize flood risk communication in the coastal area. The concern of frightening people with risk information seems unwarranted, on condition that the information is carefully contextualized. Future research should therefore focus on the effectiveness of various flood risk communication strategies. How do people process this information and how does this information affect their awareness and behaviour? Such research should be realized preferably through longitudinal or experimental studies, in order to enable causality testing. In addition, future work could focus on the feasibility and effectiveness of possible personal measures and response behaviour to further mitigate flood risks (e.g., moving heating boiler to a higher floor, assembling an emergency kit, collecting information about evacuation routes and safe locations, etc.).

The Belgian coast is about to change in the upcoming years. It will be a case to take a pro-active and anticipating attitude towards the public so to inform them properly, foster discussion and create an optimal climate for solutions that are both feasible and acceptable. Key challenge, however, will be to address both permanent and temporary residents while considering the interests and concerns of other stakeholders in the coastal area.

SAMENVATTING

Wereldwijd zijn kustgebieden onderhevig aan snel toenemende urbanisatie en tal van economische ontwikkelingen. Recente rampen hebben echter de kwetsbaarheid van deze kustgebieden aangetoond (cfr. New Orleans na orkaan Katrina in 2005; Bangladesh na cycloon Sidr in 2007; Franse kust na storm Xynthia in 2010). De voorspellingen met betrekking tot de klimaatverandering en de zeespiegelstijging dragen bij tot de groeiende bezorgdheid omtrent de bescherming van kustgebieden tegen overstromingen vanuit zee. Ook de Vlaamse regering schenkt sedert enkele jaren (hernieuwde) aandacht aan de bescherming van de Belgische kust tegen een stormvloed. Daarbij wordt een risicobenadering gevolgd, waarbij niet alleen getracht wordt om de kans op een overstroming vanuit zee klein te houden, maar waarbij ook rekening wordt gehouden met de mogelijke gevolgen (schade en slachtoffers) die een dergelijke overstroming kan teweegbrengen. Op verscheidene plaatsen (bv. in Oostende) is men reeds gestart met het nemen van maatregelen, waaronder badstrandverhoging. In de komende jaren zullen nog andere maatregelen volgen, zoals het plaatsen van (storm)muurtjes (Mertens *et al.*, 2010).

Hoewel de technische benadering van risico (kansen x gevolgen) een *objectief* en kwantitatief beeld geeft van de risico's, zijn verschillende onderzoekers ervan overtuigd dat een dergelijke benadering alleen niet voldoende is om onderbouwde beleidsbeslissingen te maken. Met name voor het optimaliseren van risicocommunicatie alsook het winnen van het publieke vertrouwen is het van belang om ook de *subjectieve* benadering van risico's in acht te nemen. Deze benadering tracht de perceptie, voorkeuren en noden van het publiek te meten en te analyseren (Slovic *et al.*, 2004). Vanuit het overstromingsbeleid groeit een steeds sterker wordende vraag om beide risicobenaderingen te integreren. In dat verband heeft verkennend onderzoek in het verleden (COMRISK project - Kaiser *et al.*, 2004) reeds aangetoond dat de Belgische kust, wat informatieverstrekking van de kustverdediging en bewustmaking van de risico's betreft, achterop hinkt ten opzichte van andere landen aan de Noordzee (Groot-Brittannië, Duitsland, Denemarken en Nederland).

Dit proefschrift richt zich op de objectieve (technische) en subjectieve (perceptie) risicobeoordeling van overstromingsrisico's aan de Belgische kust. Het beoogt zowel een overzicht te geven van de stand van zaken binnen beide risicobenaderingen (*doelstelling 1*), als een methodologische en empirische

bijdrage te leveren aan het onderzoeksveld van overstromingsrisico's (*doelstelling 2*). Het wil daarnaast elementen aanreiken voor een efficiënt communicatiebeleid ten aanzien van deze risico's (*doelstelling 3*).

Het proefschrift biedt in het bijzonder antwoord op een vijftal onderzoeksvragen, die voortvloeien uit de drie bovenstaande doelstellingen.

> *1: Wat is de stand van zaken binnen de Vlaamse risicomethodologie met betrekking tot overstromingsbeheer en wat zijn de uitdagingen voor de (nabije) toekomst?*
>
> *2: In hoeverre is het in rekening brengen van toerisme een belangrijke factor in het beheer van overstromingsrisico's in kustgebieden?*
>
> *3: Wat is de stand van zaken in het onderzoek naar de publieke perceptie en communicatie van overstromingsrisico's? Welke methodes worden gebruikt en wat zijn de voornaamste bevindingen en tekortkomingen in deze onderzoeksdomeinen?*
>
> *4: Welke factoren bepalen de publieke perceptie van overstromingsrisico's in kustgebieden? Komen deze subjectieve risicobeoordelingen overeen met de objectieve (technische), en hoe is de geografische locatie gelinkt aan iemands perceptie?*
>
> *5: Hoe kan de kennis van risicoperceptie bruikbaar zijn voor communicatie experts en wat zijn de voorkeuren en behoeftes van het publiek inzake communicatie van overstromingsrisico's?*

De hoofdstukken 2 – 6 van dit proefschrift stellen telkens één van bovenstaande onderzoeksvragen centraal.

In hoofdstuk 2 (Kellens *et al.*, 2011a) wordt een overzicht geschetst van de stand van zaken in het overstromingsbeheer in Vlaanderen (*onderzoeksvraag 1*). Er wordt aangetoond dat het beleid de voorbije tien jaar tijd is overgeschakeld van een 'bescherming tegen water' naar een 'bescherming tegen schade', met name door overstromingsrisico's (kansen en gevolgen) in kaart te brengen. De Vlaamse methodologie maakt daarbij gebruik van geografische informatiesystemen (GIS) om verschillende geografische (overstromingskaarten, landgebruik, bevolkings-gegevens, etc.) en niet-geografische (economische waarde) datasets aan elkaar te koppelen (Vanneuville *et al.*, 2006). De voorbije jaren is de detailgraad van deze berekeningen geleidelijk verbeterd, enerzijds dankzij nieuwe datasets (bv. kadastrale informatie), anderzijds dankzij technologische vooruitgang (verbeterde GIS, snellere computers). Met de invoering van de Europese Overstromingsrichtlijn stellen zich echter nieuwe uitdagingen. Onder meer dient in de toekomst meer aandacht uit te gaan naar de immateriële gevolgen van overstromingen, waarbij effecten op gezondheid, de omgeving en het culturele erfgoed zullen bestudeerd en gekwantificeerd moeten worden. Ook wordt er steeds meer nadruk gelegd op publieke participatie en communicatie; het publiek moet geïnformeerd worden over de risico's en maatregelen waaraan het blootgesteld staat, en zou, indien mogelijk, ook betrokken moeten worden in de beslissingsvorming (Mostert and Junier, 2009).

Hoofdstuk 3 (Kellens *et al.*, 2011b) bouwt verder op de risicomethodologie voorgesteld in hoofdstuk 2 en behandelt een specifieke onderzoeksleemte met betrekking tot populatiedynamieken en slachtofferberekeningen (*onderzoeksvraag 2*). Concreet wordt in dit hoofdstuk nagegaan in hoeverre het in rekening brengen van toerismedynamiek aan de Belgische kust zinvol en belangrijk is binnen overstromingsbeheer. Daartoe worden dagelijkse schattingen van het aantal verblijfstoeristen in tweede verblijven aan de Belgische kust gebruikt, en dit voor de periode juni 2007 – mei 2008. Verder wordt het gedrag van verblijfstoeristen ingeschat door hen een fictief weerbericht voor te leggen. Op basis van de antwoorden van 175 verblijfstoeristen blijkt dat ongeveer 2/3 van de toeristen zijn geplande vakantie niet zou annuleren of stopzetten, ondanks voorspellingen op stormweer (gedefinieerd als 'stormwinden van 9 Beaufort en meer, met kans op gevaarlijke situaties door overslaande golven'). Met behulp van GIS wordt vervolgens de impact van een zware stormvloed ('worst-case scenario') berekend voor de ganse kustzone. Daaruit blijkt dat het in rekening brengen van toeristen in slachtofferberekeningen tot 18% meer slachtoffers in een winterscenario leidt, en tot 40% meer slachtoffers in een zomerscenario. De reden voor deze enorme toename is tweeërlei: enerzijds is het aandeel verblijfstoeristen aan de Belgische kust op zomerdagen en topdagen (vakantie/weekend) zeer groot (verdubbeling van de bevolking tijdens de zomermaanden), anderzijds zijn de meeste tweede verblijven in een zone vlakbij de kustlijn gelegen, zodat zij des te kwetsbaarder zijn bij een stormvloed. Ondanks de beperkingen en vereenvoudigingen van het onderzoek (detailgraad data, constante inwonersaantal, geen evacuatie) toont het aan dat verblijfstoeristen niet over het hoofd dienen gezien te worden in risicomanagement. In de verdere analyses van het proefschrift (Hoofdstukken 5 en 6) wordt deze groep bijgevolg expliciet bestudeerd (naast de inwoners).

In hoofdstuk 4 (Kellens *et al.*, 2011c) wordt een literatuuroverzicht geschetst van de onderzoeksvelden van risicoperceptie en risicocommunicatie met specifieke toepassing in overstromingen (*onderzoeksvraag 3*). Daaruit blijkt dat beide onderzoeksdomeinen in de lift zitten. Meer dan 85% van de empirisch onderbouwde studies werden in de voorbije vijf jaar gepubliceerd. Echter, een aantal methodologische kinderziektes zorgen ervoor dat het perceptieonderzoek onderling nog vaak moeilijk te vergelijken is. Veel studies passen een eigen methodologie toe, waardoor er weinig standaardisatie is. Bovendien staat het onderzoek naar de communicatie van overstromingsrisico's nog in zijn kinderschoenen.

Door middel van twee enquêtes aan de Belgische kust pakken hoofdstukken 5 en 6 enkele van de aangehaalde onderzoekshiaten uit de voorgaande hoofdstukken aan. In hoofdstuk 5 (Kellens *et al.*, 2011d) staat de subjectieve inschatting van overstromingsrisico's van kustbewoners en verblijfstoeristen centraal (*onderzoeksvraag 4*). Met behulp van meervoudige regressieanalyse wordt onderzocht welke factoren mede bepalend zijn voor de risicoperceptie van het publiek. Naast persoonlijke factoren worden ook residentiële factoren (kelder, gelijkvloers, zeezicht) en locatie (hoog/laag risico) in de analyse meegenomen. De enquête werd afgenomen in Oostende ('hoog' risico) en in Knokke-Heist en De Panne ('laag' risico) (N = 619). Risicoperceptie werd gemeten aan de hand van een set vragen die door middel van factoranalyse werden gelijkgeschaald. Uit de analyses blijkt dat de perceptie in Oostende effectief hoger is dan in de andere twee gemeenten, hetgeen overeenstemt met de objectieve, technische risicobenaderingen. Verder blijkt het effect van locatie op risicoperceptie weinig of niet gemedieerd te zijn door ervaring met eerdere stormvloeden of overstromingen. Wellicht spelen andere (psychologische) factoren of processen hier een rol. Het wordt een uitdaging voor verder onderzoek om deze factoren te identificeren en te kwantificeren. Tot slot bevestigt de analyse dat ouderen en vrouwen een hogere risicobeoordeling aan de dag leggen dan mannen en jongeren.

In hoofdstuk 6 (Kellens *et al.*, 2011e) wordt de communicatie van overstromingsrisico's aan de Belgische kust onder de loep genomen (*onderzoeksvraag 5*). Daarbij wordt onderzocht welke factoren bepalend zijn of iemand nood heeft aan risico-informatie. Eerdere studies hebben in modellen deze informatienood gekoppeld aan informatiezoekgedrag, en hebben verschillende componenten voorgesteld die hierop inspelen. Echter, deze modellen zijn vaak erg complex en daardoor moeilijk empirisch te testen (Griffin *et al.*, 1999). Met behulp van padanalyse wordt in hoofdstuk 6 enerzijds een methodologische bijdrage geleverd aan dit soort modellen door relaties tussen verschillende componenten van het model empirisch te testen. Gegevens zijn afkomstig van een online enquête onder de inwoners en tweedeverblijvers van Oostende ($N = 313$). De resultaten van de pad-analyse toont onder meer aan dat permanente bewoners sneller geneigd zijn om risico-informatie op te zoeken dan tweedeverblijvers, hetgeen samenhangt met een hoger risicobewustzijn bij de eerste groep alsook een grotere kennis van overstromingsrisico's aan de kust. Anderzijds levert het hoofdstuk ook vanuit pragmatisch oogpunt een bijdrage, met name door te onderzoeken welk soort (risico)informatie gewenst is en wanneer en hoe deze best verspreid wordt. De resultaten van de enquête tonen aan dat, hoewel een minderheid van de ondervraagden wakker ligt van overstromingsrisico's, de overgrote meerderheid (ca. 90%) wel meer informatie wil ontvangen, en dat liefst op geregelde tijdstippen. Internet, televisie en brochures zijn de drie populairste communicatiemiddelen, ten nadele van radio en krant. Daarbij scoort algemene informatie (m.b.t. zeewering en actueel veiligheidsniveau) het hoogst, maar ook informatie over welke maatregelen men persoonlijk kan nemen en zelfs informatie over evacuatieprocedures worden als nuttig ervaren. Wat communicatie-voorkeuren betreft blijken tweedeverblijvers weinig of niet te verschillen van kustbewoners.

Samengevat levert dit proefschrift methodologische bijdrages voor het gebruik en de verwerking van dynamische populatiegegevens binnen risicoberekeningen en de toepassing van regressie- en mediatieanalyses binnen perceptieonderzoek. De resultaten tonen aan dat er een maatschappelijk draagvlak bestaat voor meer communicatie over de bescherming van de Belgische kust tegen overstromingen vanuit zee. Hoewel de kans op een stormvloed klein is, kunnen de gevolgen ervan zeer groot zijn voor de Belgische kust, zowel in termen van schade als slachtoffers. Ondanks het feit dat er al gecommuniceerd wordt over de bescherming van de kust tegen overstromingen vanuit zee (informatieborden, brochures, informatie-avonden), wordt momenteel slechts een zeer klein percentage van de bevolking echt bereikt. De gepercipieerde, eigen kennis omtrent een aantal risicoaspecten is klein, en de vraag naar meer informatie is groot, zowel onder inwoners als verblijfstoeristen. Het wordt een uitdaging om aan deze vraag te voldoen, rekening houdend met de belangen van de verschillende sectoren aan de Belgische kust.

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CURRICULUM VITAE

Wim Kellens was born on April 25, 1984 in Torhout (Belgium). He started his Geography education in 2002 at Ghent University, where he received a Master's degree *magna cum laude* in 2006, specializing in cartography and GIS. In his Master's thesis, Wim focused on the use of Geographic Information Systems and digital elevation models to obtain hydrographic maps, a topic that led to important contacts with Flanders Hydraulics Research (Flemish Authorities).

After his graduation, Wim started as a scientific researcher at the Department of Geography. While sent on secondment at Flanders Hydraulics Research, he worked on the European Interreg IIIb Project SafeCoast and the Flemish Master Plan for Coastal Safety. In June 2007, he received a grant from the Flemish Fund for Scientific Research (FWO) to start a PhD. During this PhD research, close contacts were made with dr. Ruud Zaalberg (Eindhoven University) and dr. ir. Teun Terpstra ($\text{HKV}_{\text{Lijn in water}}$), which led to several fruitful collaborations. Results of the PhD have been published in or are submitted to leading international journals in the domains of risk analysis and risk management. In 2011, Wim received the certificate of completing the Doctoral Training Programme at the Doctoral Schools of Natural Sciences.

Recent hazards have demonstrated the catastrophic potential of coastal floods worldwide. Expectations regarding climate change (sea level rise) and economic development (coastal urbanization) further underline the need to study these risks.

While flood risks have been predominantly approached from a technical, objective perspective, recent years have witnessed a growing concern to consider subjective aspects of these risks as well. This dissertation examines both approaches through literature reviews and analyses. In addition, insights are acquired to improve flood risk communication. Area of study is the Belgian coast, which is on the verge of improving its defence structures to assure protection against future storm surges.

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