Danish risk management plans of the EU floods directive

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ABSTRACT. – The paper evaluates the impact and effect of the EU Flood's Directive (2007/60/EC) in Denmark and the flood risk management plans that are the result of the national implementation in the first plan period (2010-2015). Twenty flood risk management plans have been elaborated and published by the 22 Danish municipalities included in 10 risk areas appointed due to a risk of floods from rivers, the sea, or both. For the municipal work, the national government has provided hazard, vulnerability, and risk assessments and maps as well as guidelines to fulfil the legal binding of the Directive. The plans are reviewed and analysed regarding main objectives and structural and non-structural mitigation measures. Conclusions point to the need of introducing better decision support systems, a need to define acceptable risks, and a need to enhance coordination between municipal and cross-sectorial actors as well as an increased effort to involve civil society is necessary. In general, the implementation of the Directive has significantly advanced the national scientific and cross-sectorial working platform for dealing with risks from floods.

Key-words: Flood Risk, Risk Management Plan, Risk Reduction, Mitigation, Awareness

Directive européenne sur les inondations : plans danois de gestion du risque

RÉSUMÉ. – L'article présente un bilan de la mise en œuvre de la Directive Inondation (2007/60 / CE) au Danemark. Vingt plans de gestion des risques d'inondation ont été élaborés (2010-2015) par les 22 municipalités danoises concernées, dans dix zones de risque d'inondation par débordement de cours d'eau et/ou submersion marine. Le gouvernement national a fourni les cartes d'aléa, de vulnérabilité et de risque, ainsi que des recommandations générales pour la mise en œuvre de la Directive. Les plans de gestion ont ensuite été mis au point, avec les principales mesures d'atténuation structurelles et non structurelles. Le bilan de cette première application montre la nécessité d'introduire de meilleurs systèmes d'aide à la décision, le besoin de définir des risques acceptables et l'importance d'améliorer la coordination entre les acteurs municipaux et les autres acteurs concernés, dont la société civile. La mise en œuvre de la directive a permis de progresser dans la gestion du risque d'inondation, que ce soit au niveau scientifique que dans l'implication des différents acteurs.

Mots-clés : Risque d'inondation, plan de gestion des risques, réduction des risques, atténuation, sensibilisation

I. INTRODUCTION

By the end of 2015 the implementation of the first 6 year plan period of the EU Floods Directive (2007/60/ EC) [EU, 2007] has potentially led to improved disaster risk reduction and preparedness measures in all member states and to cross border actions. After incorporation of the Directive into Danish legislation [Danish Ministry of the Environment, 2010; Danish Ministry of Transportation, 2010; Danish Parliament, 2009] and based on a preliminary flood risk assessment (2010-2011), 10 Danish risk areas were appointed due to potential flooding from storm surges and/or extreme river runoff [NA & DCA, 2011; Piontkowitz and Sorensen, 2011].

The appointment of risk areas and reporting was carried out in geographical units of 'river basin districts' and 'river basins' according to the EU Water Frame Directive (WFD) (2000/60/EC) [EU, 2000] (Fig. 1) by a workgroup from the Ministry of the Environment, mainly the Nature Agency (NA) with the responsibility of inland waters and the WFD, and the Ministry of Transportation represented by the Danish Coastal Authority (DCA) with coastal protection responsibilities. A flood risk assessment (2012-2013) identified tangible and intangible losses as a consequence of extreme events today and under 2050 and 2100 climate change scenarios for the 10 risk areas [DCA, 2013]. Here DCA, in close collaboration with the Leichtweiß-Institute for Hydraulic Engineering and Water Resources at TU Braunschweig (LWI), Germany, further developed the XtremRisk 'cellbased risk assessment' (CRA) method and mapping based on a 'Source – Pathway – Receptor' (S-P-R) approach for Danish conditions [Burzel *et al.*, 2012, 2015; Dassanayake *et al.*, 2012; DCA, 2013; Kortenhaus and Oumeraci, 2014; Piontkowitz *et al.*, 2014].

Subsequently, hazard, vulnerability and risk maps have been incorporated into risk reduction and risk management plans by the involved 22 municipalities (Denmark is divided into 98 municipalities of which 76 have a coastline) in the 10 risk areas in 2014-2015 (Table 1). Whereas the risk assessment and mapping was carried out by DCA, it is thus a municipal responsibility to produce risk management plans in accordance with the Directive. The overall plans published by DCA [2015a; 2015b] link to individual municipal level plans (Updated web-links in Appendix 1), and a public web-based



Figure 1 : Danish risk areas. The map shows the 10 risk areas (in red) appointed under the EU Floods Directive. Colours (violet, green, brown, blue) show water basin districts with a further subdivision into water basins indicated by colour shades.

GIS-solution exhibits maps produced in the hazard and vulnerability analyses, and risk assessments [DGA, 2015].

The paper presents challenges and learnings from the first plan period of implementation of the EU Floods Directive in Denmark (2010-2015) with emphasis on the cross-sectorial collaboration and coordination between science and national and municipal authorities in the preparation of risk management plans. The implementation and transformation of risk maps into risk management and risk reduction plans at the municipal level is presented. Focal points are the different approaches taken by the municipalities and challenges encountered in relation to legislation, local physical/geographic, demographic, and to municipal structural administration differences and conditions.

II. BACKGROUND AND METHODS

Following a brief summary of the first two phases of implementation (2010-2013), the paper details the third phase implementation of risk management plans by the involved municipalities (2014-2015).

II.1. Past floods and appointment of risk areas

With only small rivers and no previous accounts of floods comparable to those experienced across Europe over the past decades, Denmark is generally not considered as a flood-prone country. Heavy precipitation and cloudbursts are perceived as very local flood hazards. Much of the country's 7,300 km coastline is low-lying and despite many accounts of storm surges in the past, coastal flood protection schemes along e.g., the North Sea coasts mean that no lives have been lost due to sea floods over the past century [Piontkowitz and Sorensen, 2011]. However, the November 1872 Baltic Sea surge [Baensch, 1875; Colding, 1881; Dahlberg *et al.*, 2016; Jensen and Töppe, 1990] stands out with its extremely high water levels that drowned 80 persons in Denmark.

The 1872 storm surge is included together with an additional 7 events to account for the sea floods' potential in the appointment of coastal risk areas. In addition, a climate related increase in mean sea level is considered. Considering the uncertainties in climate projections and emission scenarios and for political reasons, as no national numbers for SLR has politically been communicated, a medium-term SLR of 0.3 m is applied with the uncertainty assigned to the timeframe. However, 2060 is used as year of reference to account for glacio-isostatic land motion. It is assumed that existing flood protection measures (dikes, dunes, seawalls etc.) are functional until extreme water levels exceed their height. This assumption is made due to limited resources and a lack of knowledge about constructions, in general. Historic data and accounts of river floods are scarce except for floods in the towns of Holstebro, Vejle, and Randers, all appointed in risk areas, and a few additional locations.

Methodologically, it was decided that risk areas consist of coherent areas that contain a certain minimum real estate value potentially becoming flooded and a certain number of addresses. The thresholds were politically decided at 2 billion DKK (265 million €) and 500 addresses, respectively [Piontkowitz and Sorensen, 2011] yielding a total of nine risk areas. The Koege Bay risk area consists of several areas exceeding the thresholds and was consequently gathered in one risk area with a later subdivision for modelling purposes etc. The 10th risk area, Fredericia, was later appointed due to a potentially flood prone power plant and high-risk chemical plants. Interestingly, all municipalities that replied to the public hearing were in favour of becoming appointed as a risk area: Those municipalities that were preliminarily included in a risk area, although some questioned their appointment in favour of other areas, were positive. Replies from municipalities not initially appointed all indicated that they were in favour of being appointed, too. Besides questioning the methods applied, these municipalities stated that they were interested in getting the flood risk assessed and mapped [NA, 2011]. As such, implementation of the Directive was positively perceived and welcomed by the Danish municipalities.

II.2. Flood Risk Assessments and Mapping

Prior to implementation of the Directive, Denmark had little practical experience with flood risk assessments apart from local area studies [DCA, 2004; DCA, 2006; Piontkowitz *et al.*, 2005; Piontkowitz *et al.*, 2006]. In this respect, the need for the development and implementation of a general, yet consistent method to fulfil the Directive on the national level was obvious. Also, this work had to be carried out within a limited timescale and economic budget. The present authors acknowledge that methods' development extends beyond the first plan period, and that a selective choice regarding theory and methodologies for risk assessments complying with available data is necessary.

In the project 'Hazard and Risk Mapping in Denmark' (HARIMA-DK) research results and methodologies of XtremRisk were applied on a wider scale in collaboration between LWI and DCA. The project serves as a successful example of a science-governance project that *i*) transfers research into societal use, *ii*) increases the national knowledge foundation regarding risk assessments and risk mapping,

and *iii*) transfers practical experience of application back into academia. Following a 6-step framework hazard analyses containing determination of hydraulic boundary conditions, reliability analyses, and inundation modelling; vulnerability analyses evaluating tangible and intangible losses, and flood risk assessments were carried out for each of the 10 risk areas. Correspondingly, hazard, vulnerability and risk maps were produced and delivered to the municipalities.

Throughout the production phase (2012-2013) DCA established a close connection to the involved municipalities *e.g.*, by hosting bilateral meetings and secure personal contacts so that maps as truthfully as possible represented local conditions; to transfer knowledge about risk and methods applied to the municipalities; to inform about the municipal tasks in the third phase of implementation, and to gain knowledge about the municipal structure in each of the municipalities involved. The risk areas vary considerably in geographical extent and the number of municipalities involved (*cf.* Table 1), as well as the risk source(s) and severity of potential floods vary. In addition, the municipalities were at different climate adaptation planning levels. Guidelines were published [Ministry of the Environment, 2014] to assist the municipalities in their preparation of risk management plans.

Maps were produced for 6 flooding scenarios, 2 hazard, 7 damage and 2 risk categories, respectively, in 5 grid cell sizes and yielded much information about the method performance. The number of maps was, of course, reduced for practical implementation in the risk management plans. The maps were presented by DCA and discussed at municipal meeting in order to appropriately fit their needs and varying technical solutions; to incorporate prior knowledge about

Table 1 : The 10 Danish risk areas and affected municipalities. Individual municipalities have made risk management plans. Risk areas were appointed due to a flood risk from the sea (4 areas), from streams and rivers (1) or a combination (5).

Risk Area	Municipality	Risk Source Considered
Randers	Randers	Sea water & fluvial
Fjord	Norddjurs	
Juelsminde	Hedensted	Sea water
Vejle	Vejle	Sea water & fluvial
Fredericia	Fredericia	Sea water
Aabenraa	Aabenraa	Sea water & fluvial
Odense Fiord	Odense Kerteminde Nordfyns (1 common plan)	Sea water & fluvial
Korsoer	Slagelse	Sea water
Nakskov	Lolland	Sea water
Koege Bay Subarea 1 Subarea 2 Subarea 3	Dragoer Taarnby Copenhagen Hvidovre Broendby Vallensbaek Ishoej Greve Solroed Koege	Sea water & fluvial
Holstebro	Holstebro	Fluvial

flood hazards and risks, and to merge the maps with existing data sets within the municipalities.

II.2.1. Municipal climate adaptation plans

Subsequent to the appointment of risk areas in 2011, the national government put forward legislative acts whereby all municipalities should make climate adaptation plans by the end of 2014 and integrate these into the municipal planning acts [Danish Government, 2012; NA, 2011b]. The adaptation plans mainly focus on floods from cloudbursts and the sewer systems (sewer systems were not a part of the Danish implementation of the Directive) and do not deal with climate adaptation in a broader sense, however. Within appointed risk areas the affected municipalities thus simultaneously had to make climate adaptation plans for the entire land area and a risk management plan for the part covered by the Directive.

The municipal climate adaptation plan work understandably led to some confusion about their relation to the Directive but, without discussing the content, context, and timing of the adaptation plans further here, many municipalities undoubtedly prospered from the knowledge gain and methodologies of the Directive's implementation in carrying out their climate adaptation tasks and vice versa. Some merging of 'climate adaptation' in national legislation and work in the second plan period of the Directive (2016-2021) is anticipated. As municipal plans, now including climate adaptation, are revised every four years and the Directive works with 6 year plan periods, this means that plan revisions are concurrent every 12th year. Apart from this lack of synchronization of the Directive with municipal level planning, there has been little conflict with national legislation. Issues regarding flood protection measures and permissions lie mainly within the Danish legislation.

II.3. Methods for risk management plan review

The risk management plans from the two water basin districts [DCA, 2015a; DCA, 2015b], Table 1, are reviewed in order to get an overview of objectives contained in each plan. The review analyses whether the risk management plans fulfil the criteria given by the guidelines [Ministry of the Environment, 2014] to meet the legal binding of the Directive.

In addition, the different mitigation/adaptation measures intended, priorities of the plans, and set-up to monitor progress of implementation is investigated. Collaboration between neighbouring municipalities within risk areas and across water basins is investigated, too. The purpose of the review is not to control whether the municipalities fulfil the Directive but to document the process and to improve future work. From this and the authors' work with the Directive and the involved municipalities over the past years, the paper seeks to identify matters unaccounted for in the Danish implementation of the Directive regarding legislation, methodologies, collaboration, information *etc.* To support the findings semi-structured interviews were conducted with the local emergency management and administration from two municipalities, respectively, one in each water basin district [Jebens, 2013].

The preparation of risk management plans builds on a multi-layer concept with emphasis on prevention-protection-preparedness [Van den Heuvel *et al.*, 2011]. The risk management plans must use the hazard, vulnerability and risk maps prepared and provided by DCA and the Nature Agency. The plans should be coordinated with the abovementioned municipal climate adaptation plans and take into account floods related climate impacts. According to the UNISDR [2017] disaster risk management can be understood as: "The systematic process of using administrative directives, organizations, and operational skills and capacities to implement strategies, policies and improved coping capacities in order to lessen the adverse impacts of hazards and the possibility of disaster". In this risk management forms a crucial part. It includes risk assessments and analysis, and the implementation of guidelines and policies to decrease, control or transfer risks. It is highly linked to preparedness planning which is based on comprehensive analyses of disaster risk. In contrast to risk management plans, preparedness plans have to take into account a much broader set of outcomes in both the risk reducing, response and recovery phases. This would include information management, national institutional legislation frameworks, coordination, contingency planning, capacity analysis, emergency services, and incorporate early recovery and recovery. Coordination between the involved stakeholders is therefore of great importance.

The municipal risk management plans are related to risk mitigation and adaptation but should still fulfil a number of criteria and use the maps provided by DCA. Minimum criteria need to be identified in order to secure that agreed goals are achieved. Objectives and proposed measures to achieve these goals must be stated by the municipalities together with a detailed description on the timing of implementation and of the stakeholder responsibilities. Finally, to monitor the process a description on how the implementation will be audited should be developed. According to the guidelines [Ministry of the Environment, 2014] the main objectives should be to reduce the adverse flooding impact on the health of the civil society, the environment, cultural heritage, and economical activities through mitigation and adaptation measures. The guidelines suggest that risk management planning should emphasize on cross-coordination between actors in the municipality and across municipalities and river basins. In addition, the guidelines recommend the inclusion of civil society.

III. RISK MANAGEMENT PLAN REVIEW

22 Danish municipalities have made their first flood risk management plan and have started analysing the challenges faced. For each of the risk management plans the analysis targets its content regarding main objectives, precautionary measures, and structural and non-structural mitigation measures. Regarding the latter, emergency management and preparedness planning is stated separately (Table 2). This is done to contrast the planning initiatives to more tangible measures implemented in emergency management by the municipalities.

III.1. Main objectives

The review reveals that only three out of 20 municipal risk management plans explicitly mention the four main objectives: people (civil society), environment, cultural heritage, and the economy. Whereas most of the plans mention some of the main objectives from the governmental guidelines [Ministry of the Environment, 2014], a couple of the plans completely lack this connection. The guidelines do not give a clear definition of the objectives, however, and overlaps or gaps may be included *e.g.*, that preventing damage on private property can be accounted for in 'people' or 'economy'. Many municipalities have an overarching goal to secure their

area from flooding, but it is often not possible to see whether and which main objectives are included in their work.

III.2. Precautionary measures and emergency management

Besides the main objectives the guidelines also call for information on priorities of the initiatives, on the prevention and protective measures (structural and non-structural), and on the inclusion of emergency management. Most municipalities identify the need to improve emergency management and work towards improving potential responsive actions. The priority and ranking of mitigation and adaptation projects are in many cases well established. A few municipalities do not state priorities for, or, have no well-defined objectives or measures established. This may lead to duplicated work and/or gaps since the involved stakeholders are likely to be unsure about their responsibilities. Improved preparedness planning for the emergency management is not mentioned in any risk management plan. This task is of great importance because of the interactions between risk management plans and preparedness plans, however. In addition, a review of selected municipal preparedness plans reveals that these are not well developed, and the lack of planning can potentially lead to failure during a flood event. The emergency managements are to some extent aware of this. Furthermore, they are in some cases of the opinion that in the event of extreme floods, they will not be able to cope [Jebens, 2013].

All municipalities have protective measures incorporated and most plans also contain preventive measures. The measures focus on both structural and non-structural mitigation and adaptation but there is a strong bias towards structural mitigation measures. In addition, ideas for structural measures tend to be much further developed and better described. Among non-structural mitigation measures cooperation between different stakeholders and across municipality borders and river basins has a strong focus. Unfortunately, there are generally only vague indications of how this collaboration and coordination is to take place and by whom. There is a strong focus on producing new guidelines/frameworks/ policies in most plans. This is a good first step but has to be followed up by an awareness increase. The risk management plans do to some extent include awareness increase among the civil society and businesses owners. However, awareness increase is often limited to subareas and is not distributed across the entire risk area. In this sense many municipalities signal that the iterative process of risk management through collaboration, public and stakeholder engagement, and awareness increase is slowly forming. Analyses of future problems and challenges are key elements of all risk management plans. This allows time for the municipalities to analyse positive and negative consequences of protective measures and to create sound solutions.

III.3. Collaborative efforts

The implementation of the Directive is a new task to the involved municipalities and they each have to find a viable way forward with respect to their political situation and administrational organization. Whereas floods 'that crossed municipal borders' came as a surprise a few years ago, the municipalities are increasingly becoming aware that cross-border collaboration is necessary and beneficial. In the first plan period, most probably due to a lack of time and resources, most municipalities have sought to 'guard their own back yard' in the preparation of their risk management

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plans assisted by external consultants. Most municipalities do want to collaborate ahead as indicated in their plans, however.

The three municipalities within the Odense Fjord risk area have produced one common and shared plan. Although individual parts of the risk area vary regarding size, vulnerability and risk, the three municipalities acknowledge that they "more or less face the same hazards and depend upon each other to reach both individual and common risk reduction measures" [Laursen, 2015]. The Odense Fjord risk management plan pays little attention to the main objectives (although they may be inherited in the plan) but has a strong focus on information, public involvement, and local capacity building. The plan thus contrasts all other risk management plans in its choice of another starting point for reducing the risks from flooding.

Collaboration is made between municipalities and with stakeholders in each municipality, but it is still unclear in the risk management plans whether this results in coordination and how the coordination is taking place. Neither central organizations nor responsible persons are mentioned as a part of the coordination work. As coordinating actions are difficult to control without a governing body this is a drawback in all risk management plans. This lack in coordination is also identified in interviews.

III.4. Responsibility and monitoring

Most municipalities either have the municipal administration assigned as the responsible unit or do not refer to any responsible body. Only the municipalities within the Odense Fjord risk area clearly state responsible partners. Also, the monitoring process is poorly described in all plans. Intermediate deliveries cannot be identified from the plans and they do not describe the process of how work will be conducted. Timeframes for implementation of the different projects and measures are insufficient and plans contain no information about when deliveries will be implemented. According to the Directive the measures included in the risk management plans have to be finalized within the next six years (2016-2021), which is the overall timeframe for work in most plans.

In any work, monitoring and responsibility of the process is crucial to guarantee that goals and deliveries are met to the agreed quality and time. It is therefore important that various partners agree on the goals as well as to the responsibility of deliveries and the monitoring regime. This process is not well described in any of the risk management plans.

III.5. Acceptable risk

Besides the main recommendations given by the guidelines, the analysis also identifies the level of protection the municipalities are aiming for: the accepted risk level. An acceptable risk level or level of service is often not given. This is also supported by the conducted interviews. A number of municipalities have initiated a process analysing their needs and some have defined an acceptable risk level as a minimum probability of occurrence, or, as a minimum height of protection. From the risk management plans it can be concluded that cost-benefit analyses have not been made or implemented so far. This makes a proper the decision-making process difficult and may result in suboptimal mitigation and adaptation measures.

Basically, neither the municipalities considered nor the Danish Coastal Authority have prior experiences working

with risk acceptance for large areas as in the context of the Directive, and the work on addressing risks and the process of defining and determining acceptable risk levels in a risk based framework is, indeed, still in its infancy across all governance levels.

IV. DISCUSSIONS

"Flood risk management should always be done collectively ... and the development of effective institutions are crucial to implement good risk reduction" [World Bank, 2012]

IV.1. Danish implementation of the EU Floods Directive

Discussions about duly implementation and over- or under-implementation of EU Directives *etc.* are central in Danish national politics and administration as they are in other member states. Over the past 6 years the perception of the EU Floods Directive has, in the present authors' opinion, moved from 'a minor addendum to the EU Water Frame Directive' to become a driver for dealing with natural hazards and risks in Denmark. For several reasons, amongst other that floods have not caused fatalities in a century, risk and risk perception in relation to floods has played an insignificant role in Denmark. Very little national work has previously dealt with risk assessments, risk mapping and risk management in relation to floods. Still, the risk of flooding is present, and the implementation of the Directive has contributed to a national advancement in dealing with risks.

Within the framework of the EU Floods Directive there are several degrees of freedom in the choice of approach and applied methodologies to achieve the main goal of reducing risks from floods. Denmark has followed one path from the preliminary assessment and appointment of risk areas, to the hazard, vulnerability and risk assessment and mapping and to the formulation of risk management plans by the involved municipalities within each of the 10 Danish risk areas. The work was carried out in an open process where all materials have been revised and published based on public hearings: for the first two phases by the DCA and the Nature agency, and in relation to the risk management plans by the individual municipalities to meet the requirements of the Directive. Most of the methods applied and the "workflow" and cross-sectorial collaboration can be improved based on the experiences gained from the first plan period. This means that the national approach to the appointment of risk areas and strategies to deal with risks should be further developed.

Municipal risk management plans are the overall result of implementation of the Directive, and initiatives and measures to reduce risks from flooding will mainly take place at the local level. All 22 municipalities included in the Danish risk have engaged in the process of implementation. A key to the success of the Directive in the Danish municipalities is its legal binding. The legislative framework of the Directive has been welcomed by all municipalities since it gives the possibility to create clear goals which politicians have to fulfil. The Directive enforces member states to identify current and future flood risks and prepare to mitigate them. Identification of the hazard, vulnerability and risk is crucial for well-informed decision-making but has to be followed up by risk management plans. Danish municipalities shall thus implement the suggested mitigating and adaptive actions in a 6 year timeframe.

The risk areas vary considerably according to the source of flooding, geographical extent and physical complexity, level of current protection (pathway), and in the urban structure (receptor). Also, the municipalities possess different levels of experience and knowledge about floods, and are at different levels regarding climate change adaptation and experiences dealing with flood protection. For instance, the town of Vejle (Vejle risk area) has experienced several floods from both rivers and the sea, and the municipality is currently aiming for large sluice and dike solutions. Here, the timing of the risk management plan makes it opportune. Hedensted (Juelsminde risk area) and Slagelse (Korsoer risk area) municipalities have also dealt with flood hazards and protection for a decade. In the Koege Bay risk area, where few people have actually experienced floods and existing flood protection measures have been in place for decades, some municipalities have not previously dealt with sea floods at all. For Copenhagen Municipality, often considered as a national 'first-mover' regarding climate change adaptation, the actual part being in the risk area is small and is given little attention. Within Odense Fjord risk area potential future solutions are currently being discussed, but the main focus is on the capacity building.

Comparability between the risk areas has not been assessed in detail. On focal point ahead is to secure as far as possible that risks can be compared between locations to provide for a more thorough national emphasis on risks, risk reduction and risk acceptance. The review of the risk management plans reveals that the municipalities have made their first steps towards dealing with risks from floods, however.

IV.2. Past flood risk management in Denmark

Flood risk management should include the implementation of sustainable measures that target specific threats in an identified hazard area. Ideally, the measures should be accepted by the population to create local ownership of the process. The process should also identify the socio-economic consequences. This is often done by conducting a cost-benefit analysis. Danish municipalities are currently in a modus where solutions are sought for before identifying the real hazard, vulnerability and risk. Large structural adaptive measures have often been suggested to prevent future floods. Such preventive measures could have a profound negative impact on the environment, the socio-economic situation, or, they may transfer risk to adjacent areas. In addition, solutions have often been decided upon in the short aftermath of a storm surge and may be insufficient due to a lack of knowledge, or, because all relevant stakeholders are not included.

IV.3. Danish flood risk management plans

The municipal risk management plans differ in their level of detail for implementation of measures. Some municipalities use logic frameworks to provide an overview on objectives, timeframes, responsible actors and monitoring. In contrast, other municipalities are less explicit on the goals and it is difficult to identify how the work will be carried out and monitored. In addition, not all municipalities divide mitigation and adaptation measures into a prevention-protection-preparedness framework.

All plans have a strong focus on structural compared to non-structural mitigation measures. This includes elevation of dikes or terrain, establishment of new dikes, establishment of water storages *etc*. Some measures are minor in order to prevent or delay flooding, whereas others are large. These large structures will not only keep water out of the area but may also influence the ability to remove water as a consequence of increased precipitation and a raised groundwater table. Large structural mitigation measures may therefore increase the risk. Non-structural (intangible) mitigation and adaptation measures are given less attention e.g., in the form of preparedness planning. They will increase the capacity of the society to lower the impact from flood events and can provide better and less expensive solutions compared to structural mitigation measures. Two non-structural measures are present in many plans, however: especially regarding large projects there is a focus on environmental and socio-economic impact analyses. Secondly, revisions of local emergency management plans are paid attention. The emergency management plans are undeveloped and lack fundamental requirements to mitigate a flood disaster. In addition, local emergency management staff has not conducted training related to floods in the past [Jebens, 2013].

Ideas for mitigation measures are often given without explicit consideration to what the municipality is protecting itself against, and cost-benefit analyses are not conducted. There is a need for decision-support systems regarding both structural and non-structural mitigation measures and to analyse the measures in relation to socio-economic conditions and the environmental impact. This need is identified by some Danish municipalities as well. The complexity of such a system may need trained end-users but will likely improve flood risk management in Denmark and target solutions to specific threats.

A few municipalities have defined an acceptable risk in their risk management plans. It is identified from the probability of an event, or, a defined topographic height and does not address the risk itself. As a starting point for decision-making and to learn about the risk in an area, it may be useful until more elaborate definitions are introduced. "Although Denmark has the financial and technical solutions to prepare for future flooding, currently there is a lack of thinking ahead. It is important to accept the possibility of future flooding and prepare for it at an early stage even though it will lead to unpopular decisions" [Jebens, 2013]. Some municipalities call for national guidelines or legislation that dictates the acceptable risk. It is through the iterative process of public involvement and debate that local political decisions currently have to be made, but the need for tools to deal with 'acceptable risk' is obvious. The difficulty in predicting future change also put pressure on local politicians and uncertainty often leads to a state of indecision. It can be difficult for politicians to prioritize costly flood protection measures for a future with different potential outcomes in relation to floods.

IV.4. Coordination and awareness in civil society

— Awareness in civil society must be raised to improve mitigation but this is not receiving much attention in the risk management plans except for minor focus areas. Directives, frameworks and guidelines do not by themselves improve disaster risk management and flood risk mitigation. Awareness creation is a continual and cross-cutting process that needs to take multiple issues into account. The lack of awareness towards floods should be seen in relation to other and more imminent risks to many people like threats to life or economic problems. Awareness increase should therefore link to issues of greater concern to the impacted population. A part of the legal process to implement risk management plans in Denmark is the public hearing phase. The guidelines [Ministry of the Environment, 2014] support the involvement of the civil society as it will increase ownership to the process, and this part should become a national priority in the second plan period of the Directive.

- To adapt to risks under future climate change, coordination is needed on and across all levels of governance. Most risk management plans only briefly emphasize on the importance of coordinating future work and no examples describing how this work should be performed were identified. However, the municipalities have collaborated across administrative borders and internally in the preparation of the risk management plans. For Odense Fjord risk area this resulted in a shared plan for the three involved municipalities. For the remainder of the plans, the lack of coordination in the implementation process is striking. Responsible and coordinating bodies are weakly defined; the monitoring process is not described, at the plans lack a timeframe. In addition, a lack of coordination between municipalities and governmental institutions is identified. As flood risk management and adaptation are generally resource demanding, many municipalities will have to reorganize to deal with the flood challenges. Above all, however, all municipalities have 'started the journey' into risk management through the implementation of the Directive, and they are all in the midst of finding each their way to deal with floods.

— To the Danish Coastal Authority and other governmental institutions there is also a need to reconsider tasks and ways of collaboration in dealing with risks from flooding. A continuous collaboration with the abovementioned municipalities, as well as those that have not been appointed as risk areas under the Directive's first plan period, is essential in order to learn more about risks from flooding and to advance the ways we perceive and deal with risks in Denmark.

V. CONCLUSIONS

Effects of the EU Floods Directive in Denmark are reviewed and analysed with emphasis on the preparation of flood risk management plans at the municipal level within the 10 Danish risk areas appointed in the first plan period of implementation. In general, the collaboration and coordination between science, national authorities and municipalities in the production of hazard, vulnerability and risk maps has been successful, and the incorporation of this knowledge and methodologies into the risk management plan may become a key element to change the risk awareness among municipalities and the civil society. From a qualitative study conclusions are drawn on the non-structural risk management measures still to be improved to obtain the full benefits from the Directive. Conclusions point to the need of introducing better decision-support systems, a potential need for the national government to assist in defining protection criteria and acceptable risks, and a need for better coordination in order for mitigation measures to be implemented without gaps or duplicating work.

Although vulnerability towards flooding in Denmark is usually considered low compared to other EU member states, the implementation of the Directive has led to substantial national advancements in our ways of perceiving, mapping and dealing with risks from flooding.

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Appendix 1 : Risk Management plans -

web-links to individual municipal risk management plans (All Accessed 10 April 2017)

- Randers Municipality: http://sektorplaner.randers.dk/dk/risikostyringsplan/risikostyringsplan.htm
- Norddjurs Municipality: http://norddjurs-planer.cowi.webhouse. dk/dk/risikostyringsplan_for_oversvoemmelse_randers_ fjord_-2015-2021/risikostyringsplan_for_oversvoemmelse_ randers fjord - 2015-2021.htm
- Hedensted Municipality: http://www.hedensted.dk/media/2623297/ risikostyringsplan-2015-for-juelsminde.pdf
- Vejle Municipality: https://www.vejle.dk/media/6060/risikostyringsplan-for-oversvoemmelser-vejle-midtby.pdf
- Fredericia Municipality: http://fredericia.viewer.dkplan.niras.dk/plan/43#/
- Aabenraa Municipality: https://www.aabenraa.dk/media/2787544/ risikostyringsplan-for-oversvoemmelser.pdf
- Odense Fjord (Odense, Kerteminde, and Nordfyns municipalities): http://www.odense.dk/borger/miljoe-og-affald/klima/klimatilpasning
- Slagelse Municipality: https://www.slagelse.dk/media/7548560/ isikostyringsplan-For-Oversvoemmelse-I-Udpegede-Omraader-I-Korsoer-A4.pdf
- Lolland Municipality: https://www.lolland.dk/Borger/Miljoe--energiog-natur/Klimatilpasning.aspx
- Dragoer Municipality: https://www.dragoer.dk/media/1376/dragoer_ risikostyringsplan_vedtaget-290ktober-2015_red.pdf
- Taarnby Municipality: http://www.taarnby.dk/media/1718995/ Risikostyringsplan-2014.pdf
- Copenhagen Municipality: https://www.kk.dk/sites/default/files/edoc/ d3c53acd-ffe6-490e-a181-62b565860aac/0f6ef6ac-604f-42d2-9267-2c46165a73af/Attachments/12954707-14291856-1.PDF
- Hvidovre Municipality: https://www.hvidovre.dk/Politik/hoeringerog-afgoerelser/2015/11/risikostyringsplan
- Broendby Municipality: http://brondby.viewer.dkplan.niras.dk/ DKplan/dkplan.aspx?pageId=607
- Vallensbaek Municipality: http://soap.plansystem.dk/pdfarchive/ 12_2974575_1418903870417.pdf
- Ishoej Municipality: http://www.ishoj.dk/sites/default/files/files/ Risikostyringsplan%20for%20Ish%C3%B8j.pdf
- Greve Municipality: http://www.greve.dk/~/media/Greve%20 Kommune/Borger/Miljø/Havvand/Risikostyringsplan%20 for%20stormflod%202015%202021.ashx
- Solroed Municipality: http://www.solrod.dk/media/1554069/risikostyringsplan_revideret061015.pdf
- Koege Municipality: http://www.koege.dk/~/media/Files/Pdf/Borger/ Natur%20milj%C3%B8%20og%20energi/Klimatilpasning/ Kystbeskyttelse/Risikostyringsplan%20%202016-2021%20 Kge%20Kommune.ashx
- Holstebro Municipality: https://www.holstebro.dk/Risikostyringsplan-9718.aspx