

# Study of the method 'Dynamic planning for risk management and climate adaptation' in a Danish municipal context

Methodology report



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Study of the method 'Dynamic planning for risk management and climate adaptation' in a Danish municipal context

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# Indhold

<b>1. Introduction</b>	<b>5</b>
<b>2. The DAPP method</b>	<b>6</b>
<b>3. The pilot areas</b>	<b>8</b>
<b>3.1 Description of the pilot area, Vejle</b>	<b>8</b>
3.1.1 Flooding challenges in Vejle	8
3.1.2 Risk management in Vejle at the start of the project	9
<b>3.2 Description of the pilot area, Assens</b>	<b>9</b>
3.2.1 Flooding challenges in Assens	10
3.2.2 Risk management in Assens at the start of the project	11
<b>4. Test of the method</b>	<b>12</b>
<b>4.1 Preparation of an adjusted process</b>	<b>12</b>
4.1.1 The adjusted DAPP model	13
<b>4.2 The process for the two pilot areas</b>	<b>13</b>
4.2.1 The process at Vejle Municipality	13
4.2.2 The process at Assens Municipality	20
<b>4.3 Evaluation of the process</b>	<b>25</b>
<b>5. Conclusions</b>	<b>28</b>
<b>6. References</b>	<b>29</b>



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# 1. Introduction

All Danish municipalities had to prepare a climate adaptation plan in 2013. Furthermore, 27 municipalities have been designated as areas of potential significant flood risk (APsFR), cf. the Floods Directive and must therefore prepare risk management plans for the purpose of reducing the risk in connection with flooding. For both types of plans, the municipalities present a long list of measures for handling the challenges posed by flooding, which relate to (i) prevention/planning, (ii) protection and (iii) preparedness. Although the plans often include a long list of measures, the municipalities find it hard to put the different measures into a time perspective. Similarly, it is hard to see the relationships and dependencies between the individual measures.

The Danish Coastal Authority has therefore had an interest in studying whether the Dynamic Adaptive Policy Pathways (DAPP) method could be used in a Danish context in relation to working in a structured manner with climate adaptation and risk management in the municipalities.

DAPP is an analytical method for identifying and subdividing a set of possible measures within an unknown/uncertain development framework over time, e.g. management and administration of water and flood risks under changing climate conditions. DAPP includes turning points, after which an incident or a measure ceases to fulfil the clearly indicated goal. After a turning point, further measures are necessary. If the measures are laid out in relation to each other, they can be illustrated in the form of a DAPP map, as shown in Figure 1.

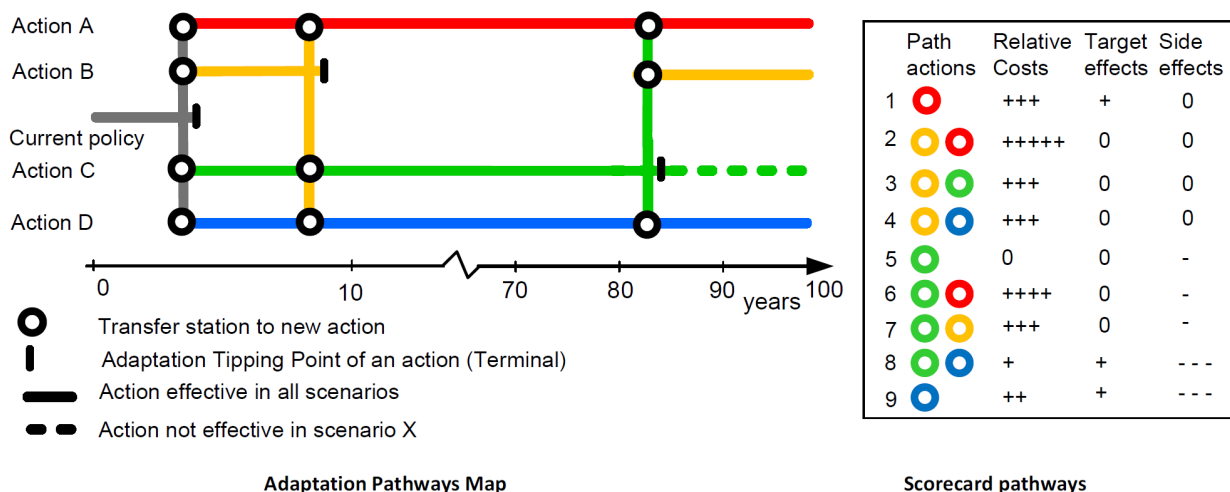


Figure 1 Example of a simple DAPP map. Table from Haasnoot, et al. (2013).

DAPP has been developed by the Dutch consultancy company Deltares. The method is described in more detail in Haasnoot, et al. (2012 & 2013) and Kwakkel, et al. (2014) and will be reviewed in detail in section 2.

The Danish Coastal Authority has studied the method by using the DAPP process in Vejle and Assens municipalities, with focus on the towns of Vejle and Assens respectively. The pilot areas and their challenges are described in section 3.

The Danish Coastal Authority then worked on reviewing the process, including implementation of the process in the two pilot areas. This resulted in an alternative DAPP process, which will be introduced at the end of the section. You can read about this in section 4.

Finally, section 5 describes the conclusions made on the basis of the study.

# 2. The DAPP method

Dynamic Adaptive Policy Pathway is a Dutch method developed for sustainable water management that takes into account the future's uncertainties. The method includes possible changes in society and environment, as well as the decisions that must be made to maintain a sustainable water system.

The DAPP method is described in the literature, and the starting point here is based on Haasnoot, et al. (2012 & 2013) and Kwakkel, et al. (2014). The method, as described in Haasnoot, et al. (2013), is reviewed briefly in this section. For a more detailed review, please refer to the literature. Here, you can also read more about the studies that form the basis for DAPP.

The DAPP process consists of 10 steps, as illustrated in Figure 2.

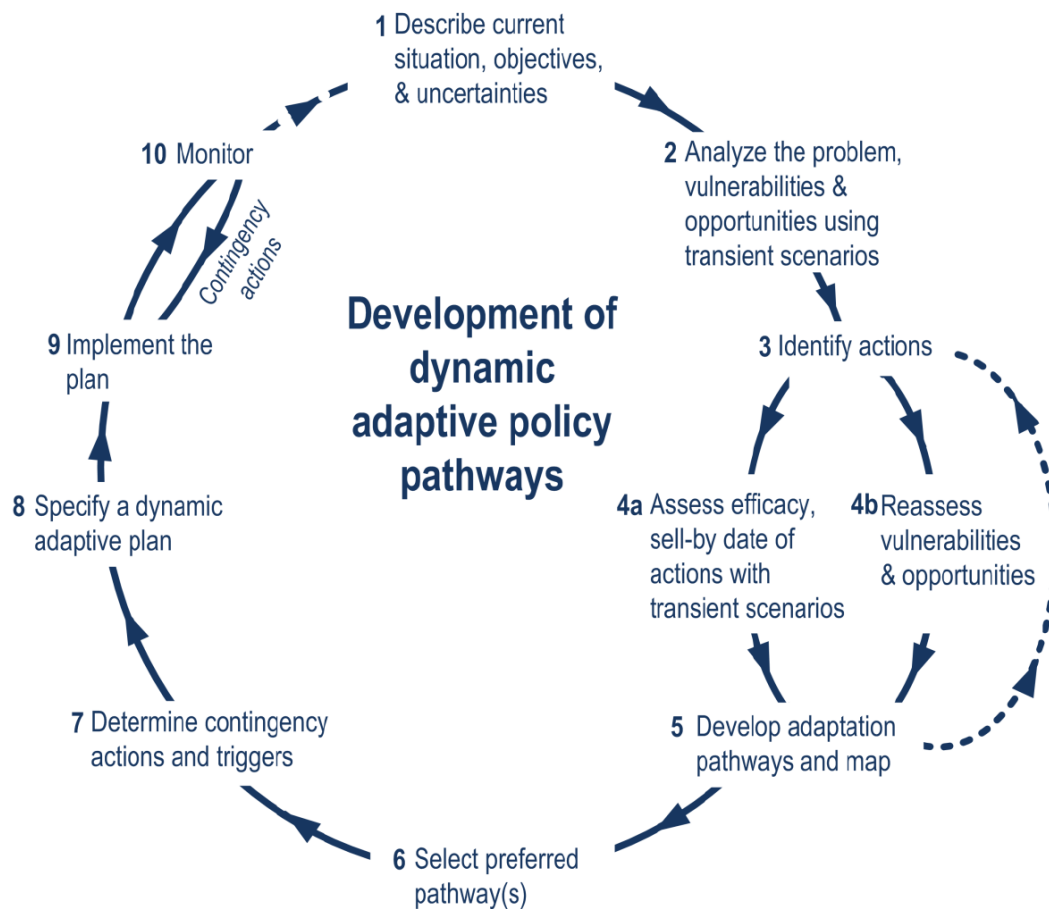


Figure 2 The DAPP process from Haasnoot, et al. (2013).

## Step 1

The first step is to describe the area you wish to work with. This includes describing the flood risk challenges and consequences as well as the related social, economic and political conditions of the area and its characteristics. This description should also cover the challenges and limitations in the area of a physical, social and political nature.

The description of the area should end in a definition of success for the area, in the form of a goal for how the area should look and what challenges have been tackled within the framework of those conditions that affect the area.

## **Step 2**

Then, a more detailed analysis of the problems in the area must be made. Here, the successes defined in step 1 are compared to the current situation in the area as well as potential future scenarios under the presumption that no changes are carried out in the area. If there are disagreements between the defined success scenario and the other scenarios this means that there is a need for action, and that opportunities and challenges in the system must be identified.

## **Step 3**

Step 3 covers identification of the potential measures that may be implemented in order to fulfil the defined success scenario within the framework of opportunities and challenges.

## **Step 4**

In step 4, the effectiveness of all the potential measures is evaluated on the basis of the different future scenarios. This enables one to identify the potential of the measures, but also their limitations. It is also studied whether the measures create new opportunities and/or limitations.

The evaluation of the measures in step 4, together with an assessment of the extent to which they fall within the limitations or create new opportunities, may create a return to step 3 in order to investigate whether there are more measures that are relevant and should be taken into consideration. If so, step 4 is repeated.

## **Step 5**

In this step, the measures are gathered together in various possible combinations. A measure can have a limitation that means a new measure is required. At the same time, a measure may rule out another measure, or there could be an illogical order that rules out certain combinations. This creates different adaptation pathways, which fulfil the defined success scenario from step 1.

It should be noted that a measure does not need to be one single element, but can also cover a group of connecting elements.

A study of the potential and limitations of the combined measures may necessitate a return to step 3.

## **Step 6**

Based on the variety of possible adaptation pathways, a number of preferred pathways should be defined. It can be a good idea to select pathways that show different perspectives. This allows those pathways that are most socially and politically robust to be defined.

## **Step 7**

The seventh step involves making the preferred pathways more robust through planning. This is done by identifying which measures/actions should be carried out in order to achieve the preferred pathways, and how these can be corrected if the future develops differently than expected.

## **Step 8**

Based on the work from all the previous steps, a dynamic adaptation plan is drawn up.

## **Step 9 & 10**

In the final two steps, those measures/actions that should be implemented first are drawn up and a monitoring system is introduced so that the development can be compared with the dynamic plan.

# 3. The pilot areas

Assens and Vejle have been chosen as the pilot areas. On the basis of the pilot areas, it will be tested whether DAPP can be used to plan climate adaptation and risk reduction in relation to flooding in a Danish municipal context. The pilot areas have been chosen as the two municipalities find themselves at different stages of their risk management, and the respective municipalities have different challenges to tackle. The towns also differ in relation to the size and complexity of the project area.

The town of Vejle was noted as an area of potential significant flood risk (APSFRR) under the EU's Floods Directive and adopted into its first risk management plan in 2015, which it has worked with since.

In recent years, Assens has worked actively with the climate adaptation of Assens town. During the startup of the DAPP project, the municipality is in the initial stages of a municipal process to identify a protection line against the flooding of Assens town and corresponding harbour areas.

The two pilot areas are described in more detail in this section.

## 3.1 Description of the pilot area, Vejle

Vejle is an old market town dating from the middle of the 13th century. The town is located at the head of Vejle Fjord, at the point where the two rivers, Grejs Å and Vejle Å, converge. The town has an area of approx. 33 km<sup>2</sup> and a population of around 57,000. Vejle's town centre is home to a number of historic buildings. The town is an attractive place to shop, and there is expansion in the coastal areas to the north and south of the harbour, both residential and commercial.

Vejle Fjord is west-facing and opens out into the northern part of the Lillebælt. The terrain around the town is relatively low, but rises more steeply on both sides of the fjord. The two rivers Grejs Å and Vejle Å flow down from the valley catchment areas of Grejsdalen and Vejle Ådal and meet in the town. Vejle Å, which is the biggest of the two rivers, is more than 30 km long, with a catchment area, Vejle Ådal, of around 250 km<sup>2</sup>. The river runs into Vejle town from the west where it meets Grejs Å. Grejs Å is around 22 km long and runs into Vejle from the north from its roughly 70 km<sup>2</sup> catchment area, Grejsdalen valley. Grejs Å splits into two branches, Omløbsåen ('the bypass river') and Mølleåen, at a diversion point north of the town. Omløbsåen and Mølleåen run through the town in a westerly and easterly direction respectively, before they both empty out into Vejle Å.

### 3.1.1 Flooding challenges in Vejle

Vejle is at risk of flooding from the rivers, the fjord and from heavy rainfall.

Flooding from Vejle Å occurs primarily in connection with long periods of heavy rainfall, while flooding from Grejs Å, Mølleåen and Omløbsåen occurs more often with intense precipitation in the Grejsdalen Valley. Flooding from the fjord occurs with storm surges, where the water is pushed in through the fjord. This occurs most often with backwash flooding, after the water has pushed through the inner Danish straits in the Baltic Sea and then moves back towards the North Sea. A statistical 100-year flood in Vejle Fjord lies around 160-170 cm (Danish Coastal Authority, 2018).

The flooding occurs widely in Vejle depending on the source as illustrated in Figure 3, and can impact the whole town, including residential areas, businesses, public services and so on.

In the long term, the town also faces big challenges with rising groundwater levels.



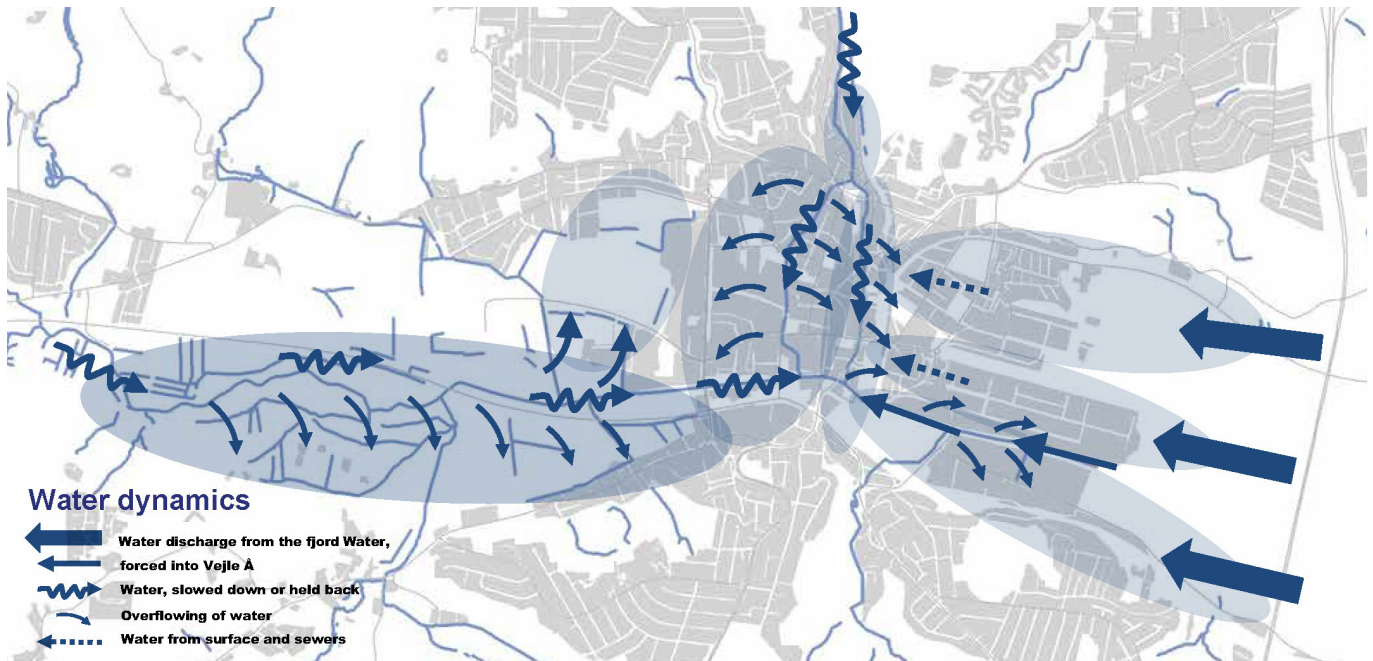


Figure 3 Flood sources and hazards in Vejle. Figure from (Vejle Kommune, 2020).

### 3.1.2 Risk management in Vejle at the start of the project

Vejle has experienced flooding on numerous occasions and has thus been working with risk management for quite a while. Vejle Municipality also adopted its first risk management plan in 2015, when the area was highlighted as an area of potential significant flood risk (APSF) according to the Floods Directive.

Measures include building flood embankments along rivers and waterways, constructing a bypass system that splits Grejs Å river into two, and building sluice gates with pumps where the bypass river 'Omløbsåen' meets Vejle Å. The terrain has also been raised along the coast in connection with new building projects.

A lot of work has been done in Vejle regarding climate adaptation. For instance, the municipality has held workshops with external partners in regard to different approaches towards tackling the flooding risks in Vejle town, and has produced some well-founded lists of possible solutions and proposals.

Risk management in Vejle is complex due to multiple water sources. Furthermore, the municipality has attempted to tackle solution proposals, economy and other challenges all at the same time. This involves critical factors, all of which are crucial for how the risk should be managed. For this precise reason, it is an almost impossible task to relate to all of them simultaneously, which has made this process difficult for the municipality.

## 3.2 Description of the pilot area, Assens

Assens is a Funen market town dating back to the 13th century. The town is situated on the west side of Funen in the south part of the Lillebælt and has a population of roughly 6,000. The town is situated in a small bay, with an isthmus (Assens Næs) that runs from the southern part of the town out into the Lillebælt.

Here, there is a marina and a cluster of holiday homes southwards from the town. The area is used for leisure and recreation and characterised by tourism. In the central part of the pilot area is an active, commercial marina and the town's shopping centre, which also includes important cultural historical elements, including access to the marina/harbour from the town. Further north, there are year-round residences.

The coastal stretch around Assens is very diverse and full of character. Rocky cliffs dominate the coast north and south of Assens along a slightly curbed coastline, shaped by narrow, primarily pebbly beaches. Assens is characterised by a particular cultural landscape, where large soil basins from former sugar manufacture in the so

uthern part of the town rise 10 metres above sea level. Assens Næs, meanwhile, is a flat, partly artificially constructed peninsula in front of the town.

The harbour and the central part of the town are located on the opposite side of Assens Næs. From here, the terrain rises rapidly towards the north, south and east. Assens has one small stream with a catchment area of around 20 km<sup>2</sup>, Kærum Å, which runs into the south part of the town from the east.

### 3.2.1 Flooding challenges in Assens

Challenges are presently faced on the flat peninsula, Assens Næs, with flooding in connection with high water events. The biggest challenges are experienced at the very tip of Assens Næs, which is affected by both flooding from the sea from the west and from the harbour basin from the east. There are various coastal protection structures in the area, including embankments, breakwaters and groynes, plus a number of jetties and landing stages.

Assens town is at risk of flooding from the Lillebælt strait, especially in connection with backwash flooding from the Baltic Sea after long periods with westerly winds, which have pushed the water into the Baltic Sea. The statistic is a 100-year flood in Assens 179 cm (Danish Coastal Authority, 2018).

In connection with high water, the town is at risk of flooding of the isthmus from both water from the Lillebælt strait and via the harbour. The terrain along the harbour varies greatly in height, and the water can flow onto the land in several places and flood the town from both the south and east. The stream, Kærum Å also brings flood risks, including from surface impoundments at high water levels.

In connection with storms, the southern part of Assens Næs can be affected by acute erosion; according to the Danish Coastal Authority's coast atlas, the risk of acute erosion on the west side of Assens Næs is classed as potentially 'great', while the risk of chronic erosion is defined as 'small'.

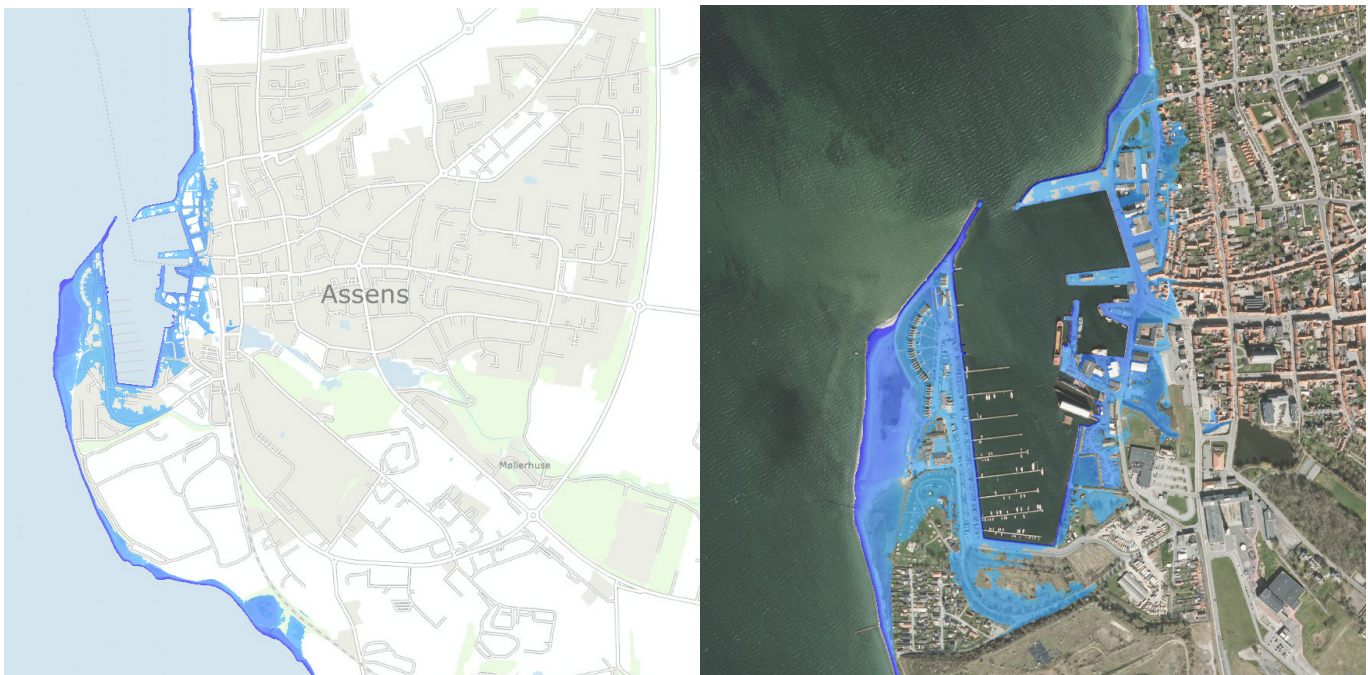


Figure 4 Potential flooding from the sea in Assens town with a water level of 179 cm, corresponding to a 100-year flood (map from SCALGO).

### 3.2.2 Risk management in Assens at the start of the project

The municipality's climate adaptation plan from 2014 targets the area around Assens Harbour and Marina as being Flood risk area due to the risk of flooding from the sea. The municipality has therefore concluded for a climate adaptation plan for Assens' harbour area, which describes how the harbour and the town can be protected against storm surges.

In the plan, the municipality has worked with the flood risk, possible locations for climate adaptation solutions/high water protection structures in the harbour area as well as the necessary safety level. The municipality has found the following potential solutions: An inner protection line and an outer protection line.

- 1) The inner protection line will be established in stages together with other planned construction projects in the area. The disadvantage here is that full protection will not be achieved until the entire protection line is established.
- 2) The outer protection line covers the establishment of a storm surge barrier at the harbour entrance. In the long term, the outer protection line could be established if the general sea water levels increase faster than expected so that the inner protection line becomes inadequate, or if the frequency of bigger storm surge events increases.

The municipal council has approved a proposal to continue working on a storm surge barrier solution at the harbour entrance, but a decision has not yet been taken as to whether these should be built. There are a number of holiday houses on the isthmus that have been subjected to flooding of the ground in front of the houses, and the owners have thus submitted a proposal on a ring dike around the houses.

The municipality wishes to take a more structured approach to the risk management, one that addresses protecting the cultural heritage sites that exist in the town. The town is also dependent upon investors who could have an interest in developing some of the coastal areas. Therefore, the municipality wishes to be flexible in regard to any future investor interests while also having a general strategy for the town that these can be a part of, so that the municipality can include risk management in any new town development.



Photo: January 2019 © Assens Municipality.

# 4. Test of the method

The purpose of the project is to study whether the DAPP approach is a good method for developing a plan for tackling flood challenges in a Danish context. The DAPP approach can be helpful for municipalities in relation to laying down guidelines and planning measures for risk reduction. This makes it crucial that this is a structured process, where it is possible for the municipalities to form an overview of what steps they need to go through in order to work further with climate adaptation or risk management in conjunction with the other elements in the municipality and the particular area.

Before testing the DAPP method in the two pilot areas, the Danish Coastal Authority held a workshop with the two partners, Kent County Council in the UK, and HZ University of Applied Sciences from the Netherlands, where the DAPP process was reviewed and discussed. The method has then been adjusted on the basis of the Danish Coastal Authority's experiences as well as meetings with the consultancy company Deltares, in order to make it better suited to a Danish context.

A test of the adjusted DAPP process itself has then been carried out in Vejle and then in Assens, with 8 meetings being held in each municipality. Adjustments to the process have been made along the way on the basis of the experiences from the pilot areas. The Danish Coastal Authority has had two additional meetings with Deltares regarding the process and specific challenges, and has also taken part in a workshop in the 2 Seas InterReg project STAR2Cs<sup>1</sup>. Finally, the process is evaluated by the two municipalities and the recommendations collected to form a Danish model for dynamic planning.

## 4.1 Preparation of an adjusted process

For many years, the Danish Coastal Authority has advised the municipalities on matters of coastal protection and, since the adoption of the EU's Flood Directive, has also advised the municipalities in question on risk management. The Danish Coastal Authority thus started the project by reviewing the DAPP process with a critical eye in order to assess whether this is a process that we understood ourselves, as well as whether it is a process that we could see being used within a Danish municipality.

At the start of the project, the Danish Coastal Authority had its first meeting with the consultancy company Deltares and TU Delft concerning DAPP, as DAPP is developed in a collaboration between these two organisations. Here, the Danish Coastal Authority received an introduction to DAPP and heard about some of the experiences, which Deltares and TU Delft have had through their work. Both institutions recommend that the DAPP process is started as a qualitative process with a broad involvement of stakeholders through workshops and so on. The preferred paths can then be calculated mathematically. The Danish Coastal Authority has assessed that the quantitative approach will be difficult for Danish municipalities to implement, as the outcome will always ultimately rely on political decisions. The Danish Coastal Authority therefore opted to work further with the method as a more qualitative process, but with quantitative input.

In the Danish Coastal Authority's workshop with the FRAMES partners Kent County Council from the UK and HZ University of Applied Sciences in the Netherlands, efforts were focused on implementing a backcasting method in the DAPP approach. Working with backcasting involves looking first at which goals shall be achieved in the future and then which changes are required to reach these goals. The workshop was also used to understand the underlying principles in DAPP and to discuss where challenges and barriers are envisaged in the process. The result became the first attempt at a revised process for dynamic planning.

A limited area was chosen for the workshop, as for practical reasons the workshop used the location of the original steps as its starting point and adjusted the method accordingly based on the experiences from these. One of the biggest changes in the method has been that step 2 of the DAPP process (see Sec-

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<sup>1</sup> <https://www.interreg2seas.eu/en/star2cs>

tion 1), where a desirable future scenario is defined, could not be completed. It was assessed that there is a need for investigating the different opportunities for tackling the challenges further before a clear future scenario can be defined. An additional step was also added, a DAPP light chart, as it made sense in the workshop to make a 'light' version of the DAPP map in order to create an overview of all the measures and their time horizons before drafting the final DAPP map. The 'DAPP light chart' is a chart where each measure is illustrated on its own without being attached to paths..

#### 4.1.1 The adjusted DAPP model

This work resulted in an adjusted DAPP process, which is illustrated in Figure 5. As can be seen here, Step 1 has been kept while Step 2 has been divided up into two parts that take place concurrently; one a brainstorm of risk-reducing measures, the other a review of the visions/plans for the area. Step 3 is a merging of these two, where for example inexpedient measures that do not agree with the visions for the area are discarded. In Step 4, the measures are laid out according to a time horizon on the so-called 'DAPP light chart', after which a relative cost-benefit analysis of the measures in Step 5 is carried out, which should end with the final DAPP map in Step 6.

The idea was that this DAPP map would show the realistic planning possibilities that exist for the area in relation to tackling the challenges with flooding, both today and in the future.

#### 4.2 The process for the two pilot areas

The pilot areas were introduced to the DAPP process and the idea behind the project from the very start. It was agreed with the municipalities that the process would be carried out in a limited forum and as a test the main purpose being to test the process with the municipalities and get their feedback on the extent to which it could work on an everyday level. It was not possible in the project to involve external partners, hold bigger workshops, involve politicians and so on. Instead, the expectations in regard to this were discussed and internal 'workshops' were held to cover what an actual workshop could bring to the discussion.

During the process, the Danish Coastal Authority had a brief discussion with Deltares as well as two longer meetings to discuss the challenges and brainstorm a little regarding the process. The brief discussion between the Danish Coastal Authority and Deltares took place in connection with Deltares' visit to Denmark in October 2018, just before the Danish Coastal Authority kicked off the process in Vejle. The two longer meetings were held in January and May 2019 alongside the process in the two municipalities.

##### 4.2.1 The process at Vejle Municipality

Vejle was the first pilot area where the DAPP process was started and where there was a particular wish to test out how DAPP would function in tackling the two flooding sources: Sea and watercourse, or even two watercourses. The municipality's project group consisted primarily of two people who were active in climate adaptation work and risk management in the town. One is a project developer in the municipality's department for project development, while the other is an engineer from the watercourses department. Both departments are part of the Technical and Environmental Administration. Other colleagues from the development department also got involved along the way, including an anthropologist, a city planner and an architect. As described in Section 2.1 Vejle has previously worked with climate adaptation and risk ma-

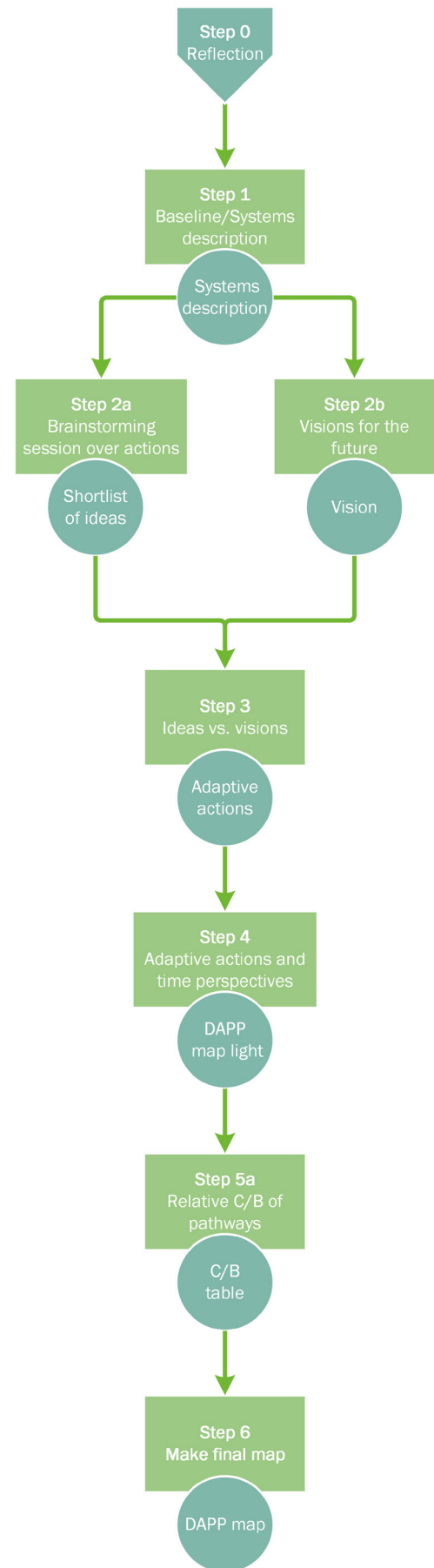


Figure 5 Adjusted DAPP process. The square boxes show the task in the step, while the round boxes show the result.

nagement, which is why the municipality was able to form a good picture of its challenges and had already prepared white papers with solution proposals.

Even though the municipality had a good understanding of the challenges it faced, step 1 was still gone through very systematically in order to clarify precisely which sources might flood which parts of the town and what the consequences of these might be. This is illustrated in Figure 6.

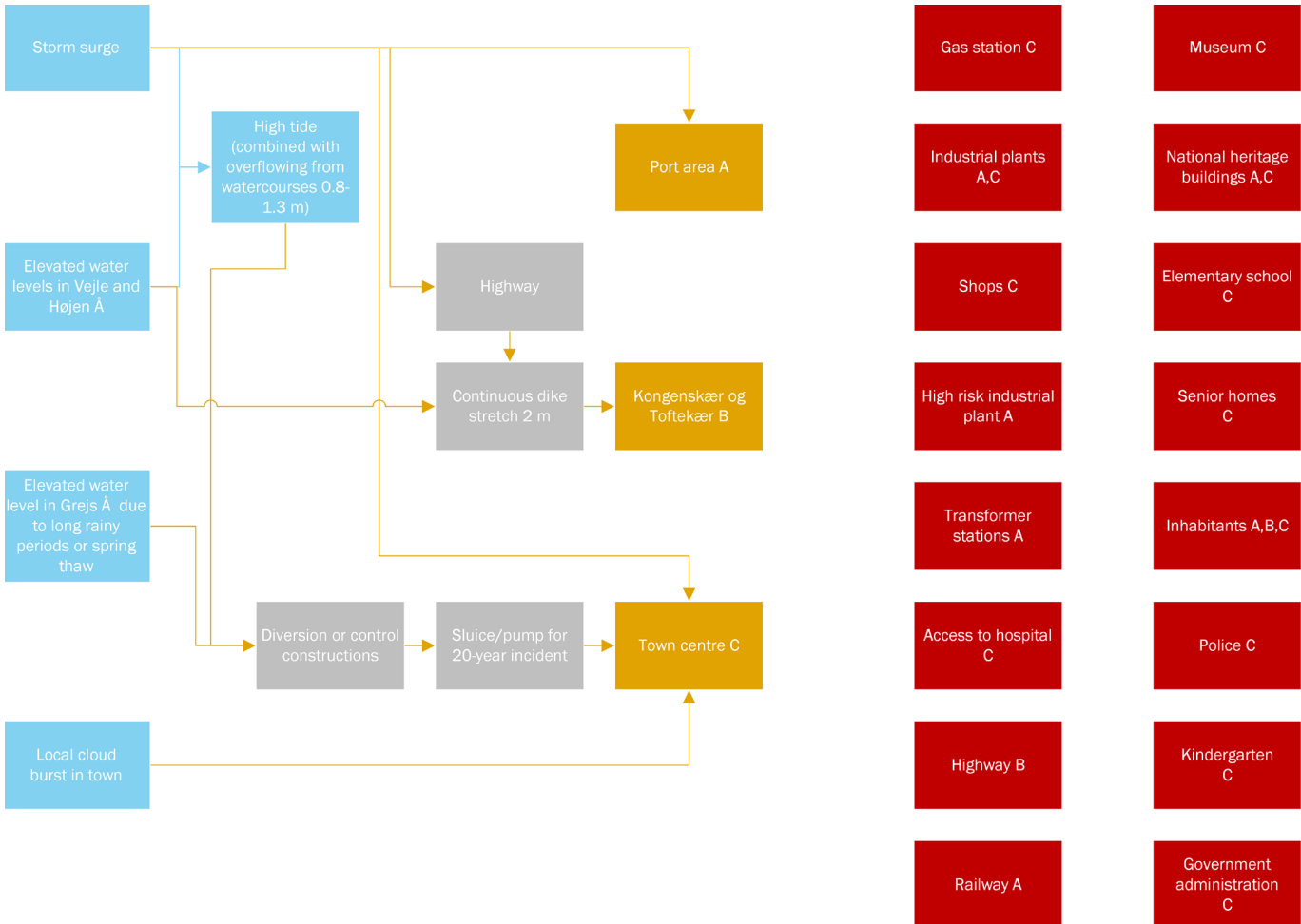


Figure 6 Source-Pathway-Receptor overview for Vejle prepared on the basis of the workshop for step 1. The blue box shows the flooding sources (source), the grey one which route the water takes (pathway), the orange what part of the town is flooded (hazard) and the red shows which elements are affected by flooding in the different parts of the town (receptor).

The experiences from step 2a show that the municipality has held workshops that have been very helpful in discussing the different possibilities for tackling flooding in the town using a variety of structures. However, very few preventative and preparedness measures have actually been outlined in these workshops, for example an updated preparedness plan, preparedness exercises, information campaigns and so on. These were added to the catalogue of measures during the work with step 2.

Because the municipal administration had already done part of the work in considering potential adaptation solutions, it had also worked on policy, financing and so on. This made the brainstorming process more difficult as there was a lot of focus on these elements. Experience showed that it was better to set these elements to one side, as this caused less of a headache in terms of tackling all the challenges at once.

It was clear in steps 2b and 3 that the municipality needed to clarify what 'the vision for the area' means. The intention of step 2b is that the considerations regarding the town's development that could affect the risk management are mapped and included in the work and choice of measures. For example, if the municipality wants Vejle to be a town by the water, and hence has a vision of easy and inviting access to the

water, then this must be addressed in the risk management. A shared understanding makes this easier to work with.

In steps 3 and 4 it was clarified which measures were relevant to work further with and an overview was made of a time horizon for the individual measures, both in terms of lifetime and implementation horizon. The measures were also classified according to the themes: Prevention, raising awareness, protection and preparedness; and it was noted which aspects of the four general adaptation strategies, which Vejle was working with at that time, they fitted under. This was then illustrated in a DAPP light chart, where each measure was outlined but not placed in relation to the other measures. The DAPP light chart is shown in Figure 7.

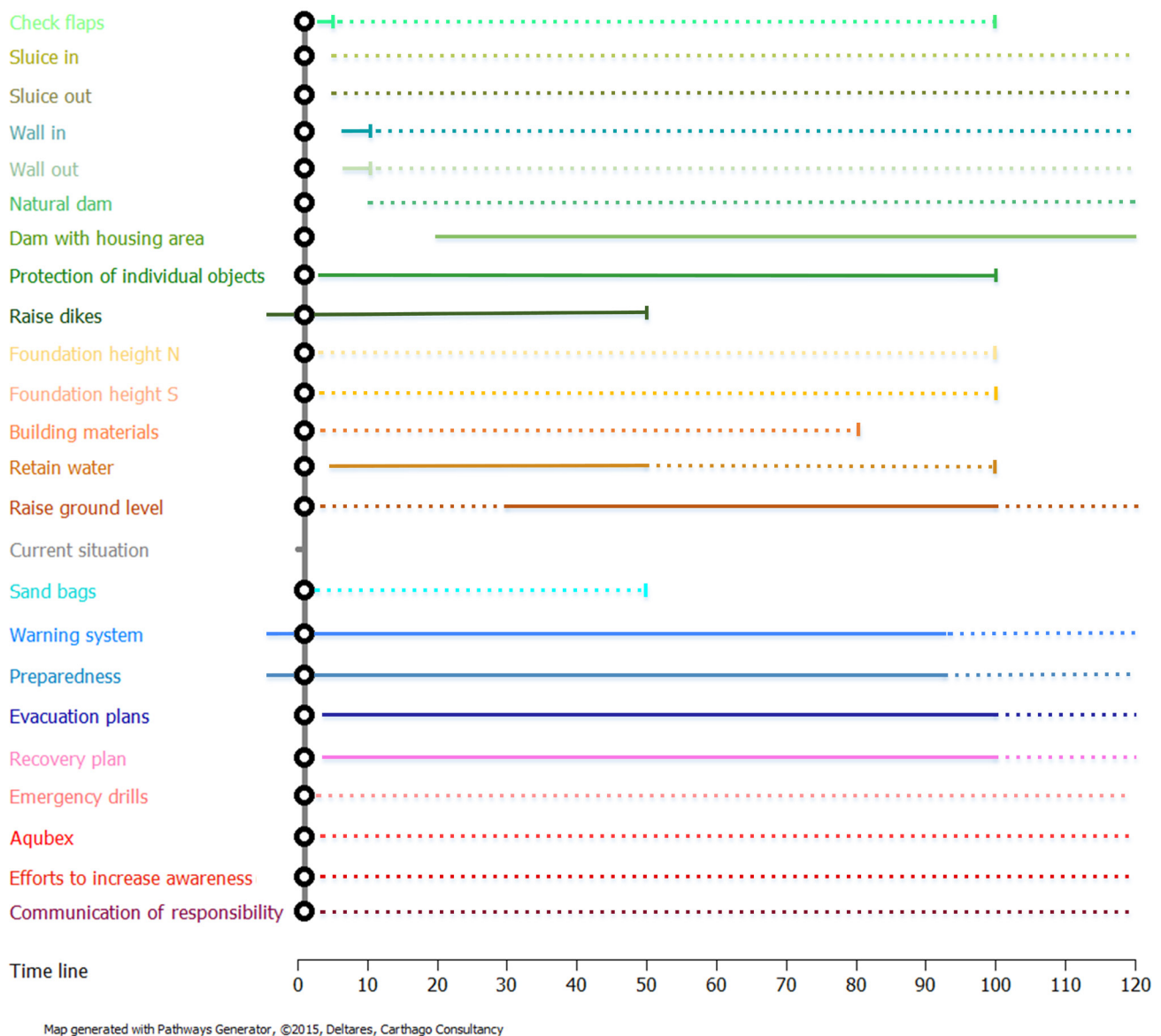


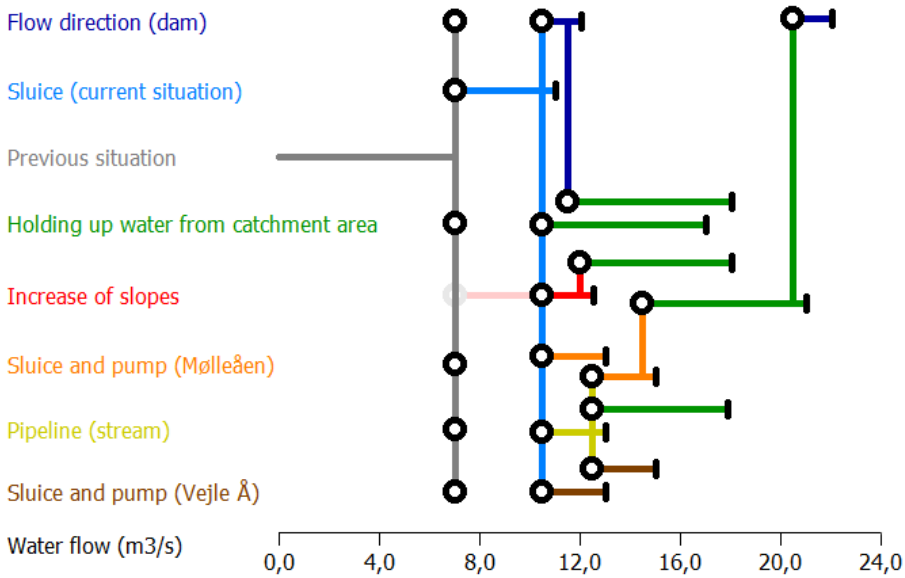
Figure 7 DAPP light chart for Vejle drawn up during step 4.

Experiences from steps 3 and 4 suggested this was not manageable. It made sense to classify the measures in themes, but on the other hand this became far too specific in relation to whether the high water wall was 2 m or 2.5 m, for example, which blurred the picture.

On the basis of the work with steps 3 and 4, the steps were adjusted to allow them to be worked on more generally. After a meeting with Deltares it was also recommended and communicated that DAPP is a pro-

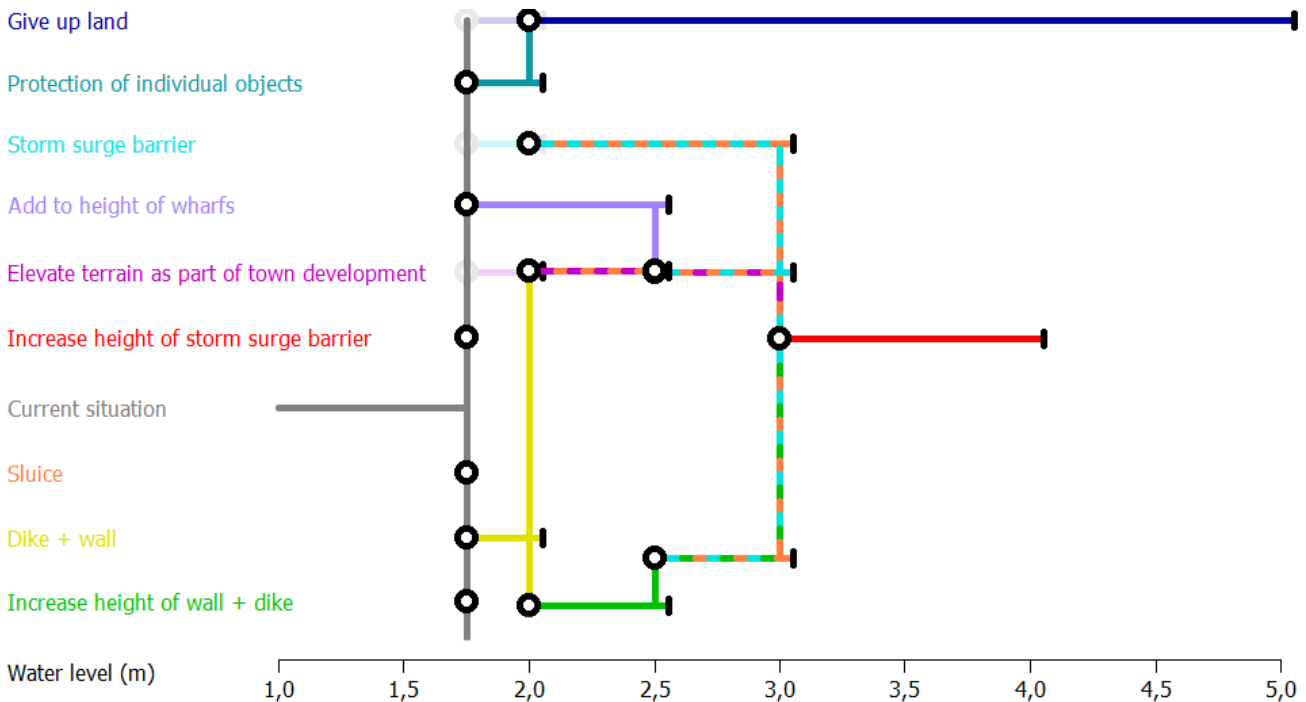
cess that ought to be started at a very general level and then made more detailed at a later point, after the first priorities in regard to limitation of adaptation pathways have been identified.

This resulted in step 4 being changed so that a final DAPP map was made here. It also turned out, however, that it was not possible to make a DAPP map that could address all the sources at once, as this became too complex. This meant that for Vejle, one DAPP map was drawn up for Grejs Å and another for Vejle town centre and the harbour in relation to flooding from Vejle Å and the fjord respectively. These are shown in Figure 8 and Figure 9 respectively.



Map generated with Pathways Generator, ©2015, Deltares, Carthago Consultancy

Figure 8 DAPP map for Grejs Å.



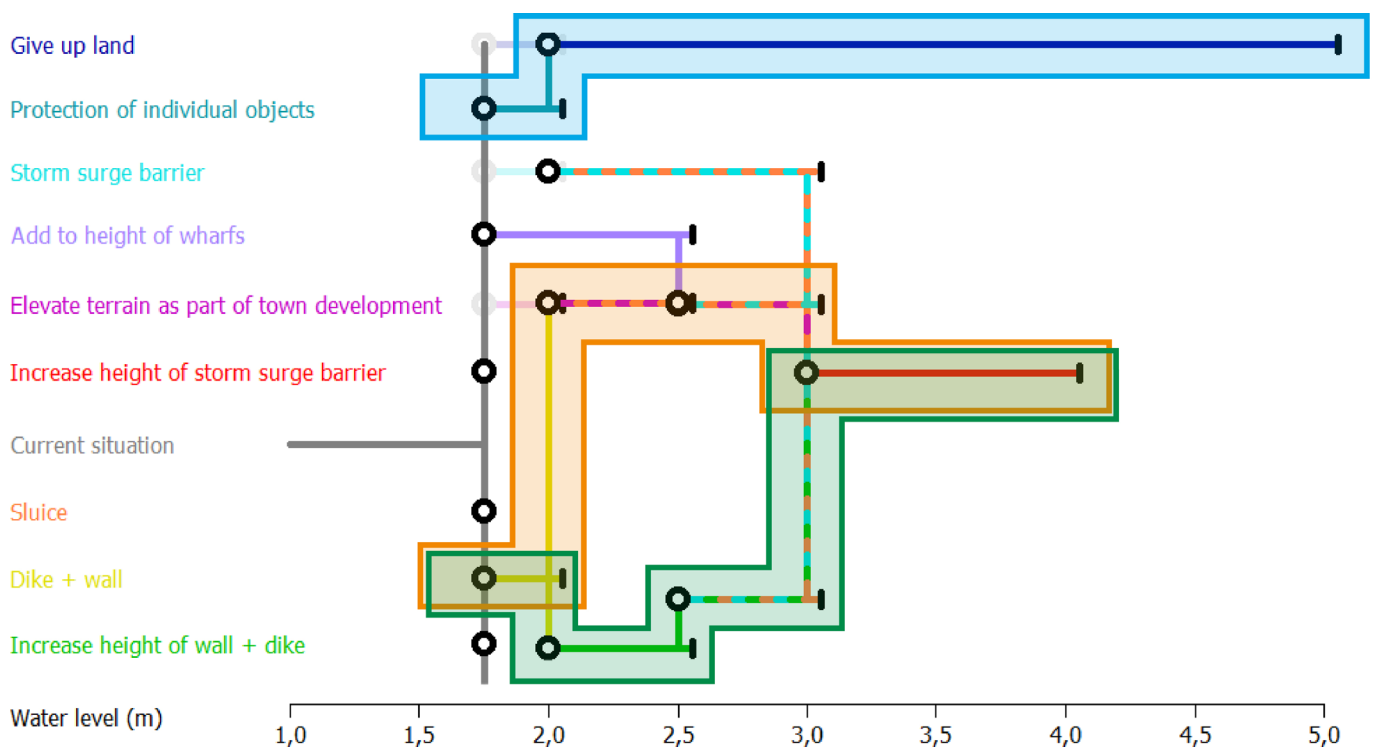
Map generated with Pathways Generator, ©2015, Deltares, Carthago Consultancy

Figure 9 DAPP map for Vejle town centre and the harbour.



For step 5, a relative cost-benefit analysis (CBA) should have been made for the different pathways in the DAPP map. Based on dialogue with Deltares, this was adjusted to a multi-criteria analysis (MCA) of the individual measures and pathways. There are various advantages to an MCA as opposed to a cost-benefit analysis at this stage of the process. Firstly, because the cost-benefit analysis is an economic calculation, and at this stage, when the experiences from the previous steps have shown that it has been necessary to work more generally, there is not sufficient detailed information for an economic analysis. Secondly, there can be other criteria, which cannot be calculated economically, that can be included in an MCA. An MCA is thus often used to support decisions. In this case, however, it is important to be aware that it is a simplified version of a multi-criteria analysis that is being used, and that carrying it out can be extremely subjective and depends greatly on the participants' personal bias and focus on the day when the MCA was carried out. It is thus recommended that the decision makers and/or stakeholders are involved in an MCA.

As the MCA needed to be carried out for Vejle, the municipality first selected three general pathways that it made sense to work with. The three pathways are shown in Figure 10. Pathway 1 is marked in green and consists of the construction of an embankment/wall along the harbour, which can be raised, the establishment of a sluice gate and finally, the construction of a storm surge barrier that can be raised. Pathway 2 is marked in orange and is very similar to pathway 1, but instead of raising the embankment/wall, the terrain in raised in connection with urban development before a storm surge barrier is built. Pathway 2, which is marked in blue, consists of object protection of the threatened elements and a subsequent relinquishment of the area, which would mean vacating the location.



Map generated with Pathways Generator, ©2015, Deltares, Carthago Consultancy

Figure 10 The DAPP map for Vejle with markings of the three selected pathways. Pathway 1 is marked with a green outline, pathway 2 with orange and pathway 3 with a blue outline.

The process began by defining which criteria should form the basis for the MCA. These would need to cover a broad range of criteria, which are crucial for the town and important in relation to the risk-reducing measures. All relevant measures were assessed for each criteria on a scale from -5 to 5, depending on the impact on the area. A total was then calculated for the pathways, where the extra criterion, flexibility, was added. The score is shown in Table 1.

Table 1 Multi-Criteria Analysis for Vejle of the specific measures and pathways.

Criteria	Measure								Pathways		
	Floodwalls and embankments	Raised floodwalls and embankments	Storm surge barrier	Sluice	Raise storm surge barrier	Protection of objects	Indicate area	Raise terrain urban development	Pathway 1	Pathway 2	Pathway 3
Ecosystem	0	0	-2	-2	0	0	0	0	-4	-4	0
Mitigation of risk	2	1	4	3	2	1	-1	1	12	12	0
Flexibility	-	-	-	-	-	-	-	-	4	3	5
Recreational additional value	1	0	4	1	0	0	-1	3	6	9	-1
Construction costs	-1	-1	-5	-2	-3	0	0	0	-12	-10	0
Municipal running costs	-1	0	-5	-3	0	0	0	0	-9	-9	0
Emergency preparedness requirements	-3	0	-4	-3	0	-5	0	0	-10	-9	-5
Taxable value	1	0	2	0	0	-2	-4	3	3	6	-6
<b>TOTAL</b>	<b>-1</b>	<b>0</b>	<b>-6</b>	<b>-6</b>	<b>-1</b>	<b>-6</b>	<b>-6</b>	<b>7</b>	<b>-10</b>	<b>-2</b>	<b>-7</b>

A weighting was then performed between the various criteria in relation to how much they ought to constitute as a percentage in the total weighting. It was then decided for example that the risk reduction ought to constitute 30% in relation to the taxable additional value, which should constitute 5%. The weighting and the adjusted MCA are shown by Table 2.

Table 2 Multi-Criteria Analysis for Vejle of the specific measures and pathways incl. weighting.

Criteria	Weighting	Measure								Pathways		
		Floodwalls and embankments	Raised floodwalls and embankments	Storm surge barrier	Sluice	Raise storm surge barrier	Protection of objects	Indicate area	Raise terrain urban development	Path 1	Path 2	Path 3
Ecosystem	5%	0	0	-2	-2	0	0	0	0	-4	-4	0
Mitigation of risk	30%	2	1	4	3	2	1	-1	1	12	12	0
Flexibility	5%	-	-	-	-	-	-	-	-	4	3	5
Recreational additional value	10%	1	0	4	1	0	0	-1	3	6	9	-1
Construction costs	15%	-1	-1	-5	-2	-3	0	0	0	-12	-10	0
Municipal running costs	20%	-1	0	-5	-3	0	0	0	0	-9	-9	0
Emergency preparedness requirements	10%	-3	0	-4	-3	0	-5	0	0	-10	-9	-5
Taxable value	5%	1	0	2	0	0	-2	-4	3	3	6	-6
<b>TOTAL</b>	<b>100%</b>	<b>-1</b>	<b>0</b>	<b>-6</b>	<b>-6</b>	<b>-1</b>	<b>-6</b>	<b>-6</b>	<b>7</b>	<b>-10</b>	<b>-2</b>	<b>-7</b>

Based on the MCA, pathway 2 is the one that scores highest for Vejle based on the selected criteria, current knowledge and existing conditions.

According to the first, adjusted process (see Figure 5) the work should now be completed, as a DAPP map has been drawn up and an analysis of the measures made. Based on the experiences along the way and input from Deltares, however, the process is not complete after the current step. Another step has been added, which is an action plan for carrying out the pathway. The action plan for the selected pathway from the MCA; pathway 2. The action plan shows which actions need to be initiated or implemented within the three time horizons for carrying out the individual measures in the pathway.

Table 3 Plan of action for Vejle via selected pathway 2.

	Short term, within 5 years (2019-2024)	Mid term (2024-2050)	Long term (2050-2070)
Storm surge barrier	<ul style="list-style-type: none"> <li>• Lobbying for changes to legislation that could cause obstacles</li> <li>• Investigate relationship to other legislation</li> <li>• Investigate funding potential</li> </ul>	<ul style="list-style-type: none"> <li>• Involve stakeholders and relevant collaborative partners (residents, neighbouring municipalities etc.)</li> <li>• Update the risk assessment and make further, more detailed studies of local conditions</li> <li>• Gathering of experience and analysis of barrier types</li> <li>• More detailed MCA and C/B analysis</li> <li>• Narrowing down the ideas and possibilities, including coupling up to other stakeholders (infrastructure, recreation etc.)</li> <li>• Specific funding potential</li> <li>• Make a decision</li> <li>• Choice of location and type</li> </ul>	<ul style="list-style-type: none"> <li>• Detailed modelling</li> <li>• Draft for organisation of operations</li> <li>• Conceptual design</li> <li>• Residents' involvement</li> <li>• Various legal frameworks put in place</li> <li>• Project design</li> <li>• Programme of operations and organisation</li> <li>• Decision on a solution and its funding</li> <li>• Permits, incl. VVM</li> <li>• Put out to tender and build in 2070</li> </ul>
Wall/embankment	<ul style="list-style-type: none"> <li>• Decide on the line of the embankment</li> <li>• Identify delegation of responsibility</li> <li>• Identify allocation of funding</li> <li>• Final specification of an adaptation strategy</li> <li>• Conceptual design (choice of solution)</li> <li>• Funding in place</li> <li>• Overall study in relation to other sources</li> <li>• Project design</li> <li>• Permits, incl. VVM</li> <li>• Put out to tender and build</li> </ul>	<ul style="list-style-type: none"> <li>• Operation and maintenance</li> </ul>	<ul style="list-style-type: none"> <li>• Operation and maintenance</li> </ul>
Raise terrain	<ul style="list-style-type: none"> <li>• Final specification of an adaptation strategy</li> <li>• Development plan and resident involvement</li> <li>• Involvement of the Marina due to potential new areas</li> </ul>	<ul style="list-style-type: none"> <li>• Assuming: The municipality takes over the areas from the Marina</li> <li>• Start-up of a partnership re. external funding</li> <li>• Specification of a development plan                             <ul style="list-style-type: none"> <li>-Design process with sketch/plan for the district</li> </ul> </li> <li>• Basis for the plan in place</li> <li>• Project design in relation to land development                             <ul style="list-style-type: none"> <li>-Funding</li> <li>-Involvement</li> </ul> </li> <li>• Put out to tender and build</li> </ul>	
Sluice on Vejle Å	<ul style="list-style-type: none"> <li>• Final specification of an adaptation strategy</li> <li>• Once the line of the embankment has been determined, the location of the sluice must also be decided</li> <li>• Investigate funding potential</li> </ul>	<ul style="list-style-type: none"> <li>• Specify ownership and secure the area</li> <li>• Conceptual design</li> <li>• Basis for the plan and VVM</li> <li>• Funding in place</li> <li>• Overall study</li> <li>• Project design</li> <li>• Permits, possibly incl. VVM</li> <li>• Put out to tender and build</li> </ul>	<ul style="list-style-type: none"> <li>• Operation and maintenance</li> </ul>

#### 4.2.2 The process at Assens Municipality

The process in Assens started after the first workshops and steps had been gone through in Vejle Municipality. The process at Assens Municipality took place according to the adjustments that were made along the way with Vejle Municipality. The project group in Assens was fixed and comprised three people: A project manager from the Environment and Nature department, who works with climate adaptation, a city planner and a representative from the Marina.

Similar to the method used in Vejle, a review of the town was carried out looking at its particular challenges, including where the water flows into specific parts of the town. Geographically speaking Assens is a smaller town than Vejle, and the challenges raised by flooding are attached to one primary source, in the form of flooding from the sea. This made it easier to dive into the specific details of elevation levels, for example, than was the case in Vejle.

Although the harbour is the primary source of flooding, Assens is also at risk of flooding from water from the sewer system during cloudbursts, the stream Kærums Å and groundwater as well as coastal erosion, which is illustrated in Figure 12. Based on the work in step 1 in Assens the town was divided up into seven sub-areas depending on the challenge, the area's characteristics and its vulnerability. These seven sub-areas are shown in Figure 11 and used in the SPR in Figure 12 to represent in a simple way which areas may experience flooding/erosion.

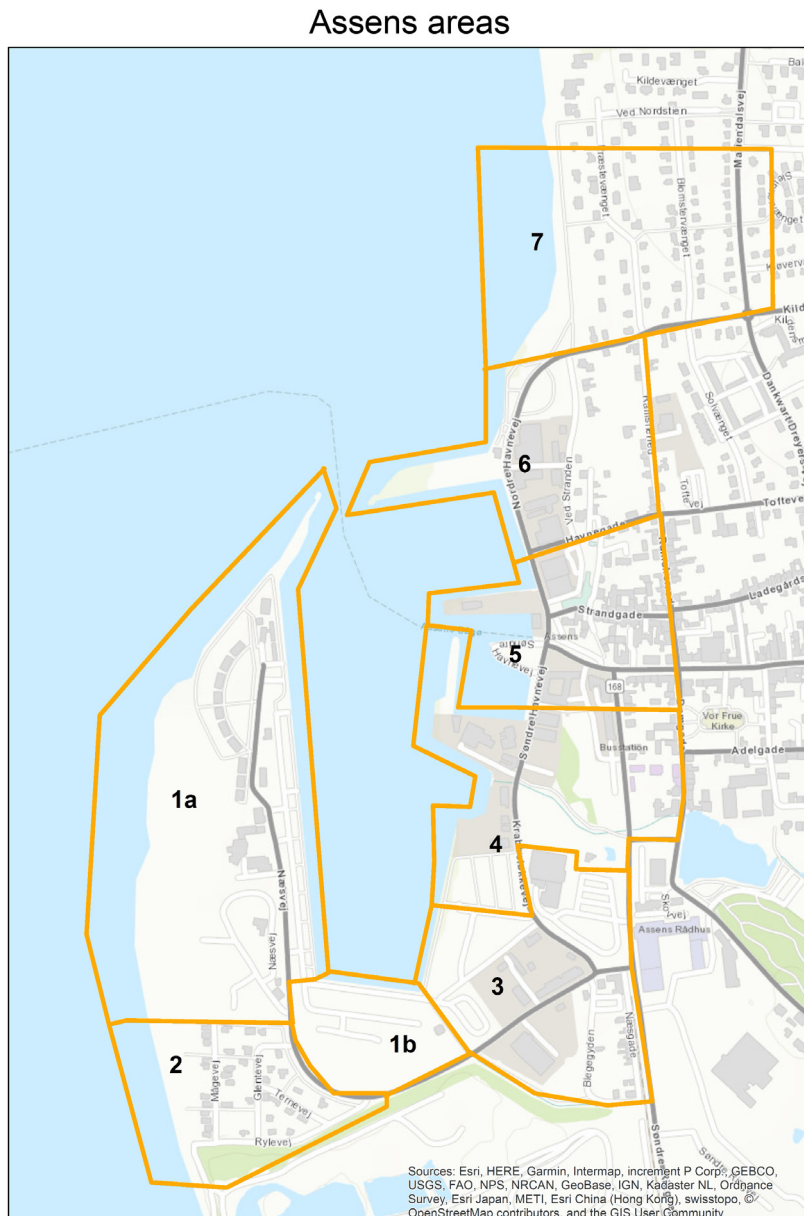


Figure 11 Demarcation of the seven areas which Assens was divided up into on the basis of the work in step 1.

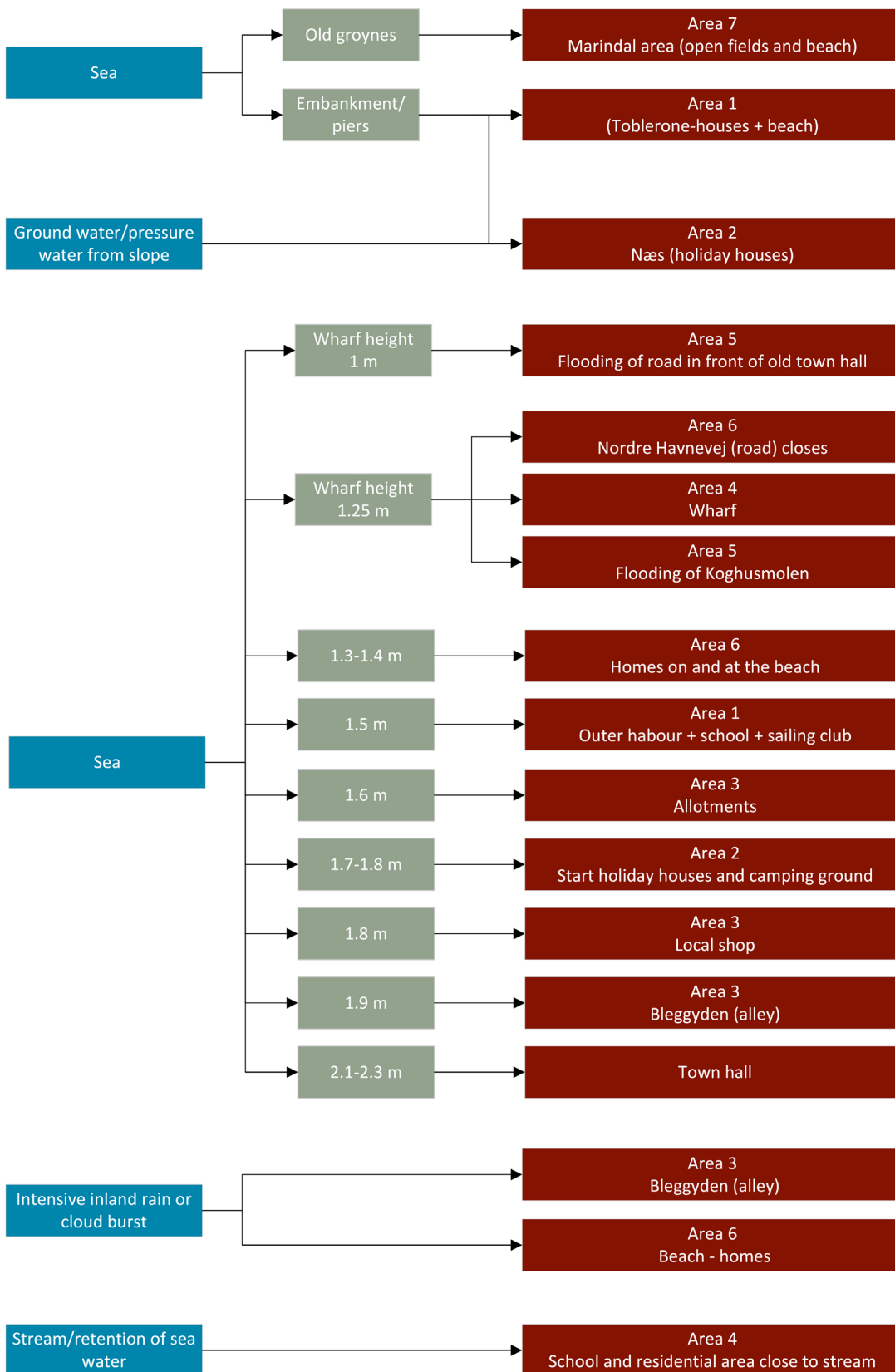


Figure 12 Source-Pathway-Receptor overview for Assens prepared on the basis of the workshop for step 1. The blue box shows the flooding sources (source), the grey-green one which route the water takes and at what elevation level flooding occurs (pathway) and the red shows what part of the town is flooded and which elements are affected by flooding in the different parts of the town (receptor).

For steps 2a and 2b in Assens, visions and brainstorming were gone through for the individual sub-areas. This was done as the municipality has many visions and specific development wishes for the town, which vary between the different areas. There is also a difference as to which measures can be implemented for the different areas,

Through the work with step 2, the project group had an in-depth discussion of the visions, among other things, which offered a shared understanding of the different viewpoints that the project participants have of the visions that could be worked further upon from a common basis. Step 2 also showed that Assens has many open spaces which the municipality would like to develop, but which depend upon finding investors. This creates an uncertain framework for what specific measures should be implemented and when. The municipality would like however to make an overall plan for the area that should ideally include everything.

Likewise for step 3, all the sub-areas were reviewed structurally in relation to the correlation between the visions and the measures from the brainstorming session, and a list of potential measures was drawn up for each sub-area.

Step 4, the drafting of the DAPP map, was a longer process that stretched out over two workshops. This was partly due to numerous discussions of the understanding of the measures, which became more specific in relation to drafting the DAPP maps than it was during steps 2 and 3. The specific measures for the individual areas were also adjusted. During the drafting of the DAPP maps some sub-areas were combined as the solutions were the same, and the DAPP maps were adjusted and amended several times during the process. It became clear during the process that there was one overall decision that affected all the other decisions. Should a storm surge barrier be constructed at the opening to the harbour or not? It also became clear that there was one measure that needed to be implemented independently of the barrier. This was a coastal cliff landscape on the outer edge of Assens Næs, which one could therefore start to plan concurrently with the DAPP process. An example of one of the DAPP maps for the areas 1a, 1b and 2 can be seen in Figure 13. The map is divided up with the geographical locations in mind. This means that measures for the outer isthmus line can be seen at the top, while measures for the inner edge of the isthmus are placed in the middle and measures directed towards the planning of new builds are shown at the bottom.

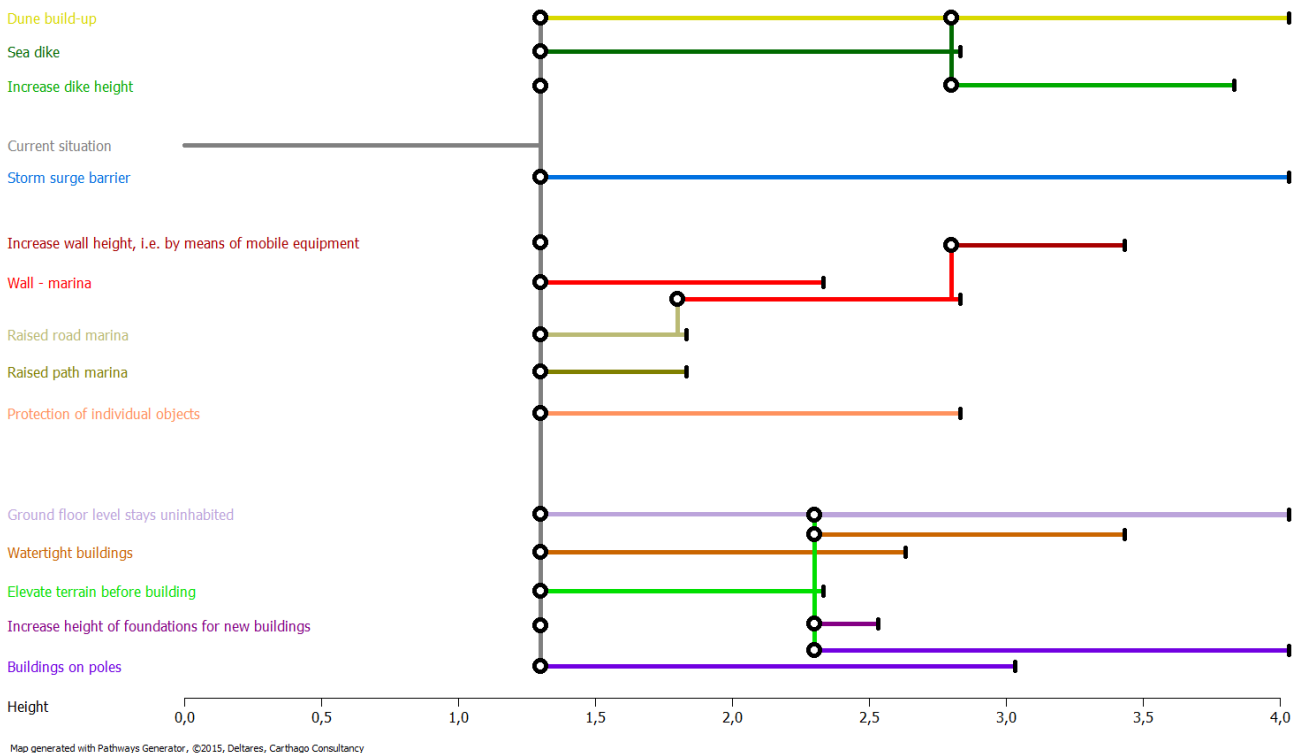


Figure 13 DAPP map for the sub-areas 1a, 1b and 2 in Assens.

As the construction of a storm surge barrier at the harbour opening affects the selection and implementation of the other measures, three general scenarios were defined regarding this decision. The measures for the three scenarios are listed in Table 4.

In scenario A, a decision would be taken today to construct a storm surge barrier at the harbour opening. It is assessed that this would take 15 years, which is why some measures must be implemented to reduce the risk until then.

In scenario B, the decision on whether to construct the storm surge barrier is postponed until 2030.

In scenario C a decision not to construct a storm surge barrier is taken today, which is why high water protection in the town must be built along the quay edges and the coastline and integrated into the cityscape.

Table 4 Summary of the specific measures for the three scenarios.

Scenario A (1.8 m) (SSB adopted now)	Scenario B (Decision postponed until 2030)	Scenario C (2.2 m) (Decision made for no SSB)
Raise road/path	Raise road/path	Raise road/path 40 cm
Raise quay edges	Raise quay edges	Raise quay edges 40 cm
Raise corner of Næsvej	Raise corner of Næsvej	High water protection gate 40 cm
High water protection gate	High water protection gate	Flood walls
Protection of objects	Protection of objects	Raised walls
Storm surge barrier	Storm surge barrier	Landscape element
	Raise road/path 40 cm	Raise landscape 1 m
	Raise quay edges 40 cm	Protection of objects
		Bulkheads

After identifying the three overall scenarios, they were assessed on the basis of the multi-criteria analysis (MCA) in step 5. It was first discussed and decided which criteria should form the basis for the MCA. The weighting of the different criteria was then laid out, which proved to be a lengthy process, as the different disciplines among participants meant that there was a big difference as to what was prioritised highest. The experiences from this showed why it is important with a broad group to make these decisions, in order for more deliberations and viewpoints to be taken into consideration.

The completion of the MCA for the specific measures did not work out optimally. This was because there were many details, e.g. the length of the high water protection, which were not included in the analysis, this being a more general assessment, but which have an influence on the financial costs of constructing the solution. Furthermore, the MCA also raised challenges in relation to the measures, e.g. scenario C contains many elements that need summarising while scenario A contains far less elements. This means there is potentially greater value for scenario C than A, which can distort the overall picture. The criterion 'Risk-reducing effect' is particularly challenging, as the method means that this criterion scores higher the more measures the strategy includes. It is therefore necessary for some criteria to give a score according to the overall strategy rather than the individual measures. The result of the MCA is shown in Table 5 and Table 6.

Table 5 Allocation of scores for the measures based on selected criteria.

Criteria	Raise road/path to 1.8 m	Raise quay edges to 1.8 m	Raise corner of road	High water protection gate	Protection of objects	Storm surge barrier	Raise road/path to 2.2 m	Raise quay edges to 2.2 m	Flood walls	Raise walls	Landscape elements	Raise landscape 1 m	Bulkheads
Design/adaptation to the urban environment	-1	-1	0	3	0	-3	-4	-4	1	1	4	3	0
Mitigation of risk	1	1	1	2	1	5	2	2	2	3	2	3	1
Use of harbour basin	0	0	0	0	0	-2	-1	-2	0	0	0	0	0
Supports tourism	0	0	0	3	0	1	-1	-1	2	0	3	3	0
Construction costs	-2	-2	-1	-3	-1	-5	-3	-2	-2	-4	-1	-1	-1
Lifetime running costs	0	1	0	0	-1	-4	0	1	-1	-3	-1	0	-2
Access to water/sea	-1	-1	0	1	0	-4	-2	-3	0	0	0	0	0
Branding value	0	0	0	3	0	2	0	0	1	1	2	0	0
Adaptability	-3	-3	-3	1	1	-3	-4	-3	1	2	3	3	1
Connection to the town	-1	0	1	3	0	0	-2	-1	1	1	5	0	0
<b>TOTAL</b>	<b>-7</b>	<b>-5</b>	<b>-2</b>	<b>13</b>	<b>0</b>	<b>-13</b>	<b>-15</b>	<b>-13</b>	<b>5</b>	<b>1</b>	<b>17</b>	<b>11</b>	<b>-1</b>

Table 6 The total score for the scenarios and the weighting of the criteria.

Criteria	Scenario A	Scenario B	Scenario C	Weighting	Weighted score A	Weighted score B	Weighted score C
Design/adaptation to the urban environment	-2	-8	1	15 %	-0.3	-1.2	0.15
Mitigation of risk	11	13	15	5 %	0.55	0.65	0.75
Use of harbour basin	-2	-5	-3	10 %	-0.2	0	0
Supports tourism	4	2	6	10 %	0.4	0.2	0.6
Construction costs	-14	-15	-14	20 %	-2.8	-3	-2.8
Lifetime running costs	-4	-4	-6	10 %	-0.4	-0.4	-0.6
Access to water/sea	-5	-8	-5	10 %	-0.5	-0.8	-0.5
Branding value	5	5	4	5 %	0.25	0.25	0.2
Adaptability	-10	-11	3	5 %	-0.5	-0.55	0.15
Connection to the town	3	1	4	10 %	0.3	0.1	0.4
<b>TOTAL</b>	<b>-14</b>	<b>-30</b>	<b>5</b>	<b>100 %</b>	<b>-3.2</b>	<b>-4.75</b>	<b>-1.65</b>

Based on the work with the pathways and the MCA it became clear that Scenario A contains a number of 'free' elements until the storm surge barrier is built, as these elements/measures must be implemented regardless of which scenario is selected. The scenarios follow the same route until the walls are constructed, and it will be after this decision that the scenarios break away from each other and take different directions. It will no longer be profitable in relation to selecting a storm surge barrier later if high water walls are built, and this decision can thus be seen as irreversible. On this basis an action plan has only been prepared until 2030, when this decision must be made at the latest. This is shown in Figure 14 and Table 7.



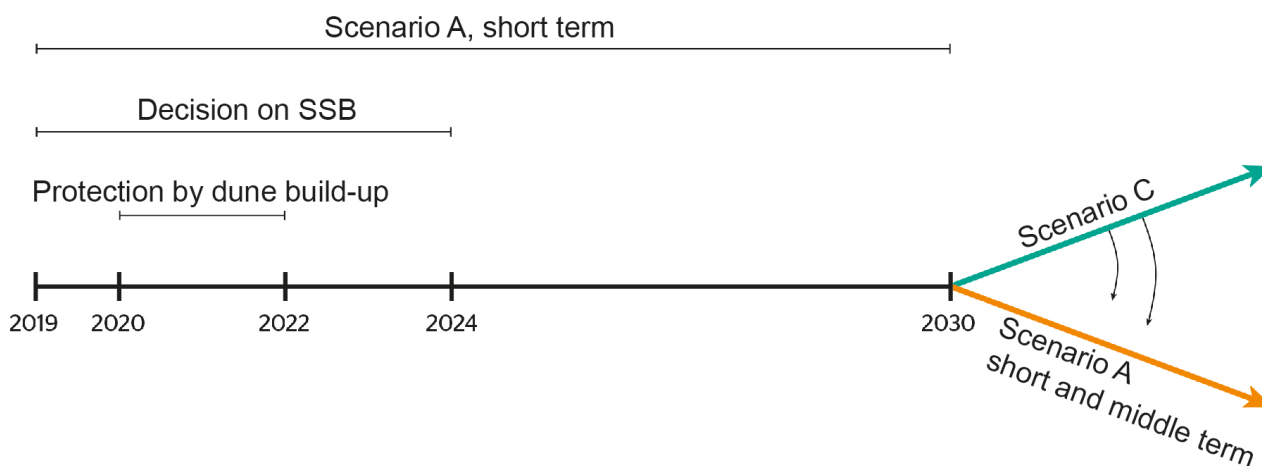


Figure 14 Overview of the scenarios that exist in practice for Assens (Graph from Assens Municipality).

Table 7 Action plan for Assens.

Year	Action
2019 - 2020	Political thematic meeting on climate adaptation and risk management, plus implementation of the process for coastal cliff landscapes. A decision must be made as to which event the town should be protected against (e.g. 100-year flood in 2050).
2020 - 2025	Work with coastal cliff landscape at Assens Næs Choice of safety level Choice of type of storm surge barrier Study of the foundation conditions Study of the opportunities for connecting/anchoring the jetties Dimensioning of the storm surge barrier Study of the construction and operating costs connected with establishing a storm surge barrier Overview of the legislative process and necessary permits.
2025	Decision on the extent to which a storm surge barrier should be established or not.
2030	The decision on the extent to which a storm surge barrier should be established must be made now at the latest.

### 4.3 Evaluation of the process

Based on the experiences from the two municipalities, some changes were made to the methodology as well as the process itself. The focus shifted from preparing yet another DAPP map to it being the process and the last step in particular that helps the municipalities moving forward. The process, which was adjusted on the basis of the pilot trials, is illustrated in Figure 15. Many changes have been made in terms of the process, which was initially developed (see Figure 5 in section 3.1). Partly, the idea of a 'DAPP light chart' has been ditched. In addition, the cost-benefit analysis has been changed in favour of a multi-criteria analysis, and an additional step has been added, which is drawing up an action plan (step 6). Furthermore, a step 0 has been added. It deals with a balancing of expectations regarding the work, as it is important for the municipalities to know what the process can help with as well as what its limitations are.

After the finalised proces is the work with monitoring and following up ont he work added to the process. This work can lead to running the process again, for instance for a smaller area og in high level detail.

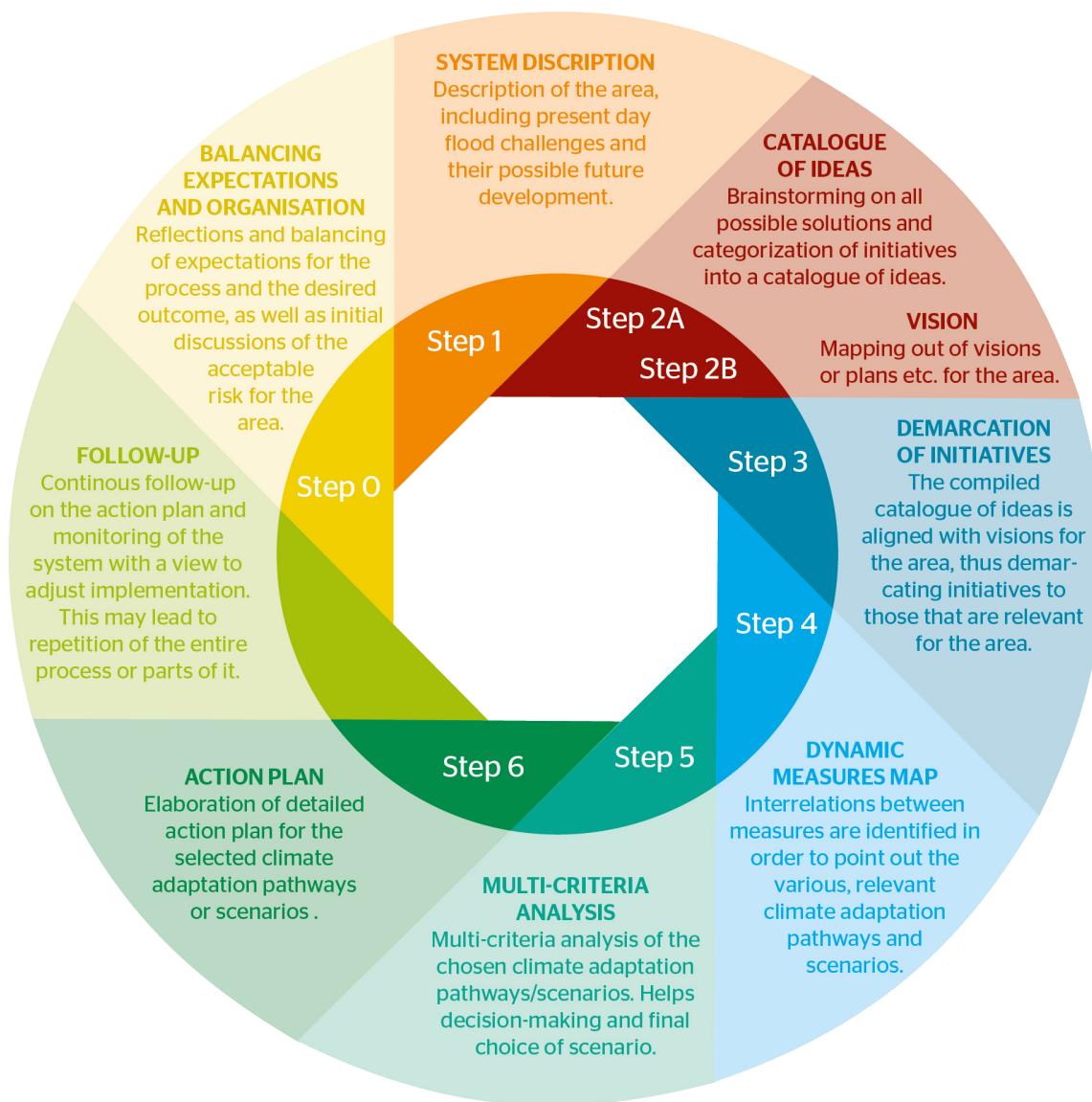


Figure 15 The adjusted process for dynamic planning.

After the process had been carried out in both municipalities, the Danish Coastal Authority carried out a joint evaluation with the project participants from both municipalities.

One of the main conclusions from the evaluation is that it is the process itself, facilitated by the Danish Coastal Authority, which provides value for the municipalities. This process enables the municipality to structure its discussions and gain greater understanding of the challenges (step 1) and opportunities which it has. Furthermore, the Danish Coastal Authority's facilitation gives them regular specialist support and coaching regarding the different solutions they are working with, including in step 2A.

The degree of detail in the process, both in the form of potential solutions, the DAPP map and the MCA, depends greatly on the size and complexity of the area, as well as how far the municipality is in its work in the specific area. In some situations the process comprises a very general approach, while in other situations it is necessary to take a more detailed approach. Likewise, the visions for the specific area can vary greatly. If the municipality does not have any visions beforehand, it may be necessary to make do with the municipal plan and the local plans already made for the area in order to move forward with the process.

The DAPP map itself (step 4) quickly becomes too complex and unmanageable when every single measure is added to it. The DAPP maps offered more value when they were made in such a way that the different pathways were clarified to capture the essence of the overall ideas that were involved without going into detail regarding the necessary placement or height of a high water protection gate.

The work with the multi-criteria analysis (MCA) can present some challenges, as not all the information may exist to an adequate extent. This may also potentially depend heavily on how the participants feel on the day in regard to the weighting between the different criteria and the scores for the individual measures.

The final step, the action plan, proved extremely valuable for the municipalities. This gave an overview of the actions that must be taken in order to move forward and also clarified deadlines for the specific pathways. The action plan gives a summary of those things which the municipality must have sorted out in order to make a decision and bring the whole process together effectively.

The Danish Coastal Authority envisaged that the process ought to be completed with the involvement of residents and politicians at different stages. There was slight disagreement between the municipalities as to what made most sense. On the one hand a broader process regarding the white paper has significant value, while on the other this can take such a long time that the entire process is drawn out for longer than the municipalities would like. In general, the municipalities recommend that the process ought to take six months.

# 5. Conclusions

The Danish Coastal Authority has carried out the dynamic planning process with two municipalities. On the basis of the process, both municipalities have developed their work with climate adaptation and risk reduction. Vejle Municipality has drawn up a proposal for a storm surge strategy that includes the experiences and results from the process. Similarly, Assens Municipality has structured its possibilities and laid out a route towards a decision regarding a storm surge barrier at the harbour opening, and also laid out measures for a coastal cliff landscape that would need to be carried out for all scenarios.

The conclusions from the trials in the two pilot areas show that it is the entire process, especially the multi-criteria analysis and the action plan, which help the municipalities to structure the various possibilities and to clarify which actions should be taken to help them move forwards, despite the need to develop the multi-criteria analysis further. Moreover, the process can be carried out for larger as well as smaller areas and with different starting points, simply by taking this into account when implementing the process.

The DAPP map can quickly become too complex if there are multiple flooding sources or if the areas have very different solutions. The DAPP map should therefore be divided up into more sections, depending on sources and sub-areas. It is not the DAPP map itself however that helps the municipalities to move further with the process. The DAPP map is a step along the way, and it should be kept simple if it is not to become unmanageable. Nor is it possible for the DAPP map to include preparedness measures or large parts of the preventative measures, such as information campaigns. The DAPP map may only include elements that mitigate the risk more measurably, such as the construction of high water protection gates, basement spot heights and so on, which permanently reduce the risk.

It is the assessment of both the Danish Coastal Authority and the municipalities that the municipalities cannot presently carry out this process alone. Implementation of the process requires a facilitator with specialist expertise within risk reduction and climate adaptation, as the specialist support in particular during the process is extremely valuable for the municipalities. Furthermore, both processes triggered an array of specific problems along the way, regarding for example laying down pathways, where all the local conditions are taken into consideration. This is complex and requires a deeper understanding of the idea behind the DAPP maps itself and the process involved. It cannot be expected that the individual municipalities have these kind of skill sets readily available.

It is, however, the recommendation of both the Danish Coastal Authority and the municipalities that more municipalities work with dynamic planning as a process for tackling flooding risks and climate adaptation.

Based on the testing of the dynamic planning in the two pilot areas, the Danish Coastal Authority concludes that dynamic planning is a suitable and supportive process in the municipalities' work with risk reduction and climate adaptation. Based on the experiences from this project, the Danish Coastal Authority is drafting guidelines for dynamic planning directed towards the municipalities. In addition, some of the experiences from the project have already been added to the Danish Coastal Authority's updated guidelines for drawing up risk management plans for areas of potential significant flood risk, see the Floods Directive. (Danish Coastal Authority, 2020).

Although the Danish Coastal Authority already recommends the dynamic planning process for risk management and climate adaptation, it is not expected that the process which the Authority currently recommends on the basis of the project will be the final solution, but that it will be amended further as more experiences are gathered. More specifically, the Danish Coastal Authority's also assesses that the multi-criteria analysis can be developed so that some of the challenges Assens had with the MCA are adjusted.

It is the Danish Coastal Authority's recommendation that the dynamic planning process be worked upon further and that more municipalities complete this process for their own risk management and climate adaptation.

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