Urban Flood Protection Chart (UFPC)

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Abstract
Already in Ancient Times, world populations were drawn towards rivers. Nowadays, waterfronts are especially attractive for luxurious dwellings and recreational activities. Refurbishment of former harbour areas into attractive living and leisure districts can be seen throughout the world. In these urban waterfronts, sufficient protection against floods is essential. However, these flood structures are likely to be present in the same realm. Simultaneous improvement of the flood defence and the refurbishment of the riverfront are hard to achieve. The objective of this paper is to develop a decision tool which can contribute in realising a harmonious riverfront from both, urban planning and flood control, point of views. This has been realised through the development of the Urban Flood Protection Chart (UFPC). The UFPC is a matrix in which two datasets are combined: the dataset of urban images and the dataset of flood retaining structures. The matrix gives an overview of which combinations between the two datasets are possible and which are less likely to become a success. The UFPC can be of help with the design of a new waterfront, or an alteration of the existing waterfront, by a team of urban planners and flood controllers, especially during the primary design cycle.

Keywords
Decision tool; flood protection; river cities; urban planning

INTRODUCTION

Already in Ancient Times, world populations were drawn towards rivers. Rivers were ideal for transport, supported agriculture and provided drinking water. Especially in developed countries, many cities grew due to the increased commercial activities in the Middle Ages. Cities expanded towards more low-lying areas. Dikes were constructed and even rivers were diverted to give the growing cities better flood protection. By the beginning of the Twentieth century most rivers in developed countries have lost their natural appearance. This can be seen for instance in the Rhine river basin in Europe. Many flood plains were transformed into urban districts or trade centres and led to bottlenecks in the river system. Since the beginning of the Twentieth Century, cities throughout out world have grown substantially. For instance, Tokyo has grown from about 3.7 million inhabitants in 1920 to more than 12.5 million people in 2005.

Figure 1: Dutch urban waterfronts: Dordrecht, Arnhem and Nijmegen

Friction urban functions – flood control

Urban functions and flood protection claim the same area of the waterfront (Figure 1). Waterfronts are especially attractive for luxurious dwellings and recreational activities. Since the end of the Twentieth Century water is seen as added value and the slogan ‘living with water’ is often heard. Refurbishment of former harbour areas into attractive living and leisure districts can be seen throughout the world. These newly developed areas as well as other districts, mostly historical city centres, need sufficient protection against floods. These structures are likely to be present in the same realm. Mostly quay walls or a combination of dikes and water retaining walls are used for flood protection in urban areas. Improvement of these structures stumbles upon resistance from local residents. Horizontal expansion of the flood defence leads to taking down buildings or diversion of roads in most cases. Furthermore, vertical expansion is often inevitable but also leads to decrease in value of the area. Contact with the river is often lost. Thus, improvement of the flood defence as the refurbishment of the riverfront is extremely difficult. The spatial claim of urban functions will remain and the traditional structural measures, such as water retaining walls or dikes are not suitable to relieve the friction between the different functions in densely populated areas.

CONCEPT OF ADAPTABLE FLOOD DEFENCES

Simultaneous improvement of the flood defence and the refurbishment of the riverfront are extremely hard to achieve. The concept of Adaptable Flood Defences (AFD) can bring relief in this matter (Stalenberg 2006). Structures like car parks, buildings, dwellings or roads are transformed and redesigned with the additional capability of protection the hinterland against floods. Firstly, the AFD concept integrates several functions into one multifunctional structure. The surplus volume along the spatially limited and popular waterfront is possible and justified through combining requirements for different urban functions. The weakness of constant friction between different functions is converted into the strength of this concept. Secondly, the AFD concept applies to structures which are adaptable. Through these adjustments, the structure has a longer lifespan, leading to sustainable structures which anticipate future changes. Finally, the AFD concept leads to synergy. In the past urban planners and flood controllers were only working on their own territory and they created boundaries which interfered in each others working space. Nowadays a dialogue is seen between the two actors. The concept of adaptable flood defences can intensify this corporation. Urban planners no longer have to cope with the forbidden zone of the conventional flood defences. Furthermore, flood controllers, who are for instance working at water boards, are not solely focusing on the flood defence and its reservation zones but shift towards a broader view including urban activities. Flood controllers and urban planners are stimulated in working together.

OBJECTIVE

The AFD concept aims at decreasing the difficulties of improving the flood protection structures at an urban waterfront and refurbishing the same urban waterfront. The AFD concept gives a reflection on how to deal with this friction between urban flood control and urban development. It describes several characteristics and features; however it does not give practical information or guidelines on how to apply this new approach. The question in this paper is therefore how this friction can be solved in a more practical way, taking the AFD concept as point of departure. The objective of this paper is to develop a decision tool which can contribute in realising a harmonious riverfront from both, urban planning and flood control, point of views.

DEVELOPMENT OF THE UFPC DECISION TOOL

For the development of the UFPC decision tool, two methods are used. Firstly, a list of requirements shows the wishes and demands from the different stakeholders. A harmonious riverfront can only be established if most of the different stakeholders' requirements are met. The UFPC decision has to be development within this framework. The AFD concept has also been developed with the use of these requirements. Secondly, an overview of existing reference decision tools, applicable in the field of flood protection, gives inspiration for the development of the UFPC decision tool. The references show what kind of information can be given in a decision tool and to what extend this information could be elaborated. Furthermore, they show possible interface designs. Combining both methods gives the Urban Flood Protection Chart.

Requirements for a harmonious riverfront

Stakeholders like the local residents and the urban planners of the municipality have several demands and wishes concerning for instance the attractiveness and accessibility of the riverfront. Alterations of this riverfront due to refurbishment of the area or due to the improvement of flood structures could be approved, but only if these wishes and demands are taken into account. If the urban planners of the municipality would have full play for the refurbishment of the riverfront, the end result would be optimal according to these urban planners. In reality this is almost never the case. The riverfront does not only have to be appealing to the public, it should also be a safe guardian for the hinterland against floods. Therefore, the flood controllers have several demands and wishes concerning this riverfront. Urbanisation or refurbishment of the riverfront could be accepted or approved, but again, only if the wishes and demands of the flood controllers are taken into account. If the flood controllers would have total control on the river front, the river cities would be protected by robust flood structures, which have little failure mechanisms and which are easily accessible for maintenance and improvement. The area would be forbidden for the public. In real life this is however not possible, because other stakeholders, like the previous mentioned urban planners, also have a say in this matter. The challenge is to fulfil as much wishes and requirement from both urban planners and flood controllers as possible.

The analysis of the wishes and demands of the different stakeholders gives several important requirements. Firstly, both urban planners and flood controllers agree on one thing: “river cities need to be preserved and protected against floods”. Cities are contributing to the economic development of a country and provide employment for both its local residents and for people living in the rural areas. Many river cities also have a long history which has mostly resulted in cultural heritage. Secondly, the following urban requirement needs special attention: “preservation or an increase of the quality of the riverfront concerning sight, accessibility and noise” Most inhabitants find it a privilege to live along the riverfront, where they can enjoy the beauty of the river and the passing vessels. However, flood structures tend to decrease this quality. Flood walls of concrete or steel are not likely to contribute to the river's beauty. Refined design might turn this negative aspect around. Thirdly, space needs attention. Both urban requirement “sufficient space for the refurbishment of existing urban riverfronts” and technical requirement “space for maintenance and construction of the flood structures” are difficult to realise. Urban development is only possible if this space is available. On the other hand, if there is not enough space for flood control, the flood structure cannot be maintained and improved as it should be, resulting in a less safe flood system. The flood structures should be accessible. Finally, “the use of flood structures with a small number of failure mechanisms” is seen as an important technical requirement. The smaller the number of failure mechanisms, the better the flood structures can be monitored. The probability of failure of these structures can be better understood and it is easier to prevent failure.

Overview of reference decision tools

For this research three decision tools are used as references. These references are analysed to give inspiration for both the contents and layout of the UFPC decision tool. The first decision tool (Pols, Kronberger et al. 2007) is developed by Ruimtelijk Planbureau (Spatial planning agency) and it aims at a reduction of the risk of flooding through the use of spatial adjustments, through better use of the administrative instruments and through changing the public opinion. The focus is on a combination of preventing floods and anticipating on a flood. The decision tool is a table of possible measures, in combination with possible sub measures, for which several specifications are given. It gives information about the effect of each measure and on which locations it can be applicable. The reader uses this information for judging which measure would have the highest potential in a certain case.

The second decision tool (Project spankrachtstudie 2002) is developed by a consortium of different Dutch governmental institutions, such as ministries, provinces, municipalities and water boards. It aims to maintain the current safety level in the river area and simultaneously it aims to contribute to the spatial quality as much as possible. The focus is on a combination of spatial and technical measures which have a reducing effect on the water level in the main Dutch rivers. The decision tool is a catalogue of these measures which are described in detail. It gives information about the effect of each measure and on which locations it can be applicable. This decision tool works similar to the first one; the reader uses the catalogue for judging which measure would have the highest potential in a certain case.

The third decision tool (Consortium of Dura Vermeer, bre et al. 2007) is developed by a consortium of contractors, municipalities and other companies. It aims at the clustering of important knowledge about water storage and the construction of waterproof dwellings in the same area. The focus is mainly technical. The decision tool is a matrix in which the rate of success is given between specific types of water storage and specific types of dwellings. Every type and the rate of success are discussed in detail. This decision tool differs from the first two, because the matrix consists of two components. The matrix already judges the given information; the reader simply reads the matrix.

An analysis of these three references leads to useful recommendations for the development of the UFPC decision tool. It shows that the interface is not universal. However, each interface should be clear and should give sufficient background information. It is therefore important to define whom the decision tool is meant for. Every stakeholder has a different background and can interpret the decision tool differently. This has also consequences for the type of measures which are presented in the decision tool. Are they purely technical or are other types involved? Furthermore, it is important to state for which spatial area the decision tool is applicable. Looking back to the analysis, each reference decision tool has a different field in which it is applicable; the second decision tool is only applicable along rivers on a broad scale, whereas the third decision tool is applicable in polders on a detailed scale.

URBAN FLOOD PROTECTION CHART

The Urban Flood Protection Chart (UFPC) consists of two datasets: urban images and flood retaining structures. The first dataset gives an overview of possible urban waterfronts; the second dataset gives an overview of technical possibilities in blocking water. The datasets are combined in a matrix: the UFPC. Both datasets and the matrix are discussed below.

Urban images

Urban images show the possible shapes of urban fronts and urban objects which deal in some sort of way with water. This is not restricted to floodproof or flood adaptive designs but it could also deal with activities which need water. Consider for instance rowing or swimming. The development of the urban designs is done through the use of the brainstorm method, the analogy method and the intuitive method (Stalenberg and Vrijling 2007). The large dataset is transformed into a list of nine urban images through clustering similar designs (Figure 2). These urban images are visions of different waterfront. They aim at giving inspiration to the users of the UFPC. In all urban images, two water levels are drawn. The light blue refers to the SLS (serviceability limit state); the dark blue refers to the ULS (ultimate limit state).

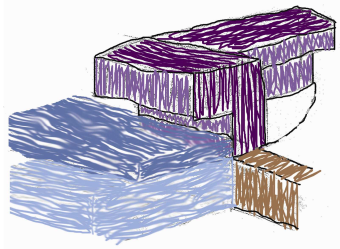
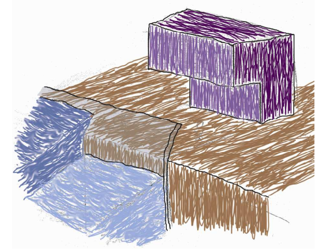
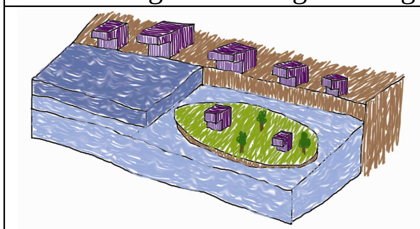
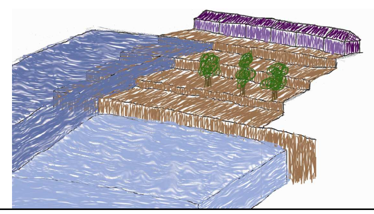
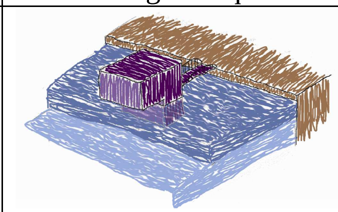
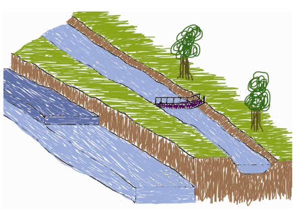
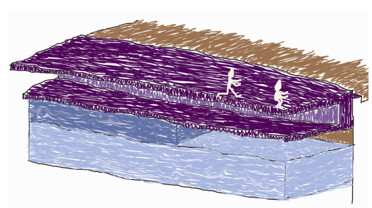
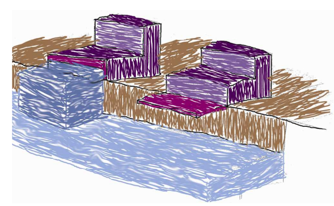
		
Urban Image 1: moving building	Urban Image 2: urban dike	Urban Image 3: aqua wall
		
Urban Image 4: island	Urban Image 5: super quay	Urban Image 6: water building
		
Urban Image 7: easy water	Urban Image 8: split level	Urban Image 9: moving objects

Figure 2: Nine types of urban images

With UI1 'moving building' the waterfront can change its appearance and appeal, depending on ideas of the designers. UI2 'urban dike' implies the transformation of a conventional green dike into an urban dike. The rural features of the dike are kept, but at the same time the dike is enriched with an urban quality. UI3 'aqua wall' creates softer weather conditions along the waterfront, due to the fact that the wall also functions as a screen which blocks wind. The aqua wall could be an interesting structure in areas with bars or restaurants. During flood conditions, the wall retains water giving a protected hinterland and a spectacular view along the quay. UI4 'islands' creates a playful scenery with a more gradual change from water to earth, than for instance a super quay. The fluctuating water level gives a constantly changing scenery of accessible and inundated islands. UI5 'super quay' is a very broad and high quay which consists of many smaller quays. The different quays are all connected which each other and are easily accessible. Every quay can be used for different urban activities in which the frequency of specific water levels is taken into account. In this image, UI6 'water building', water is used as an urban element. Red and blue are combined, creating a playful view. All water buildings are waterproof and can resist changes in water level.

UI7 ‘easy water’ focuses on the accessibility of a waterfront. A dike is likely to create a barrier between the city and the river. With the introduction of a second waterfront, water can be easily reached and the barrier of the existing dike is reduced. UI8 ‘split level’ focuses on the integration of urban functions which aims at the separation of these functions. By moving or rotating objects, UI9, the riverside will change its appearance. These objects can vary in shape, size and purpose.

Flood retaining structures

This section gives an overview of technical possibilities for the realisation of the floodproof urban designs (Stalenberg and Vrijling 2008). These flood retaining structures are based on the guidelines of the ENW (former TAW: Technical Advisory Committee on Water Defences) and on fieldwork in the Dutch Rhine cities (Technical Advisory Committee on Water Defences 1998). The structures can be divided in three categories (Technical Advisory Committee on Water Defences 1998): earth structures, special water retaining structures and hydraulic artefacts. Earth structures are weight structures which are naturally formed by morphology or which are constructed with mainly earth materials. Special water retaining structures are used in areas where other functions are present causing insufficient space for earth structures. Hydraulic artefacts are mainly applied at utilitarian crossings and cause gaps in the flood defence. Examples of crossings are structures for navigation and water management. Within these categories the following distinction can be made: temporary structures, which are only placed and used during a short period of time; permanent movable structures, which are constructed at location and cannot be stored elsewhere; permanent immovable structures; which only differ from the previous category due to the fact that they are not movable and therefore always present in the urban realm; and combined structures, which are a combination of the above mentioned structures.

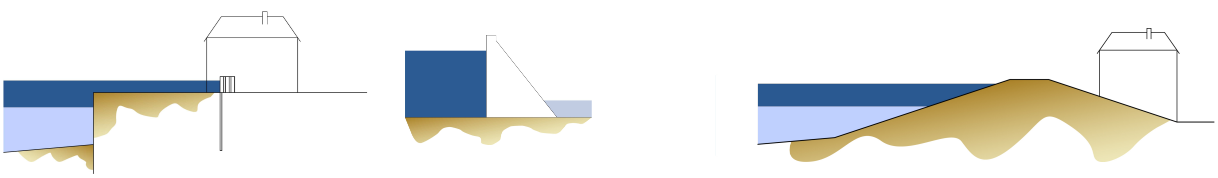


Figure 3: examples of flood retaining structures: stop logs, dam and dike
(light blue refers to SLS state; dark blue refers to ULS state)

Stop logs are an example of combined structures within the category special water retaining structures (Figure 3). They are used for filling up gaps within the flood defence or for adding extra height to a permanent flood defence. Stop logs are always used in combination with permanent structures and are only placed during flood conditions. The structure is sealed with rubber profiles for a maximum reduction of leakage. In general, stop logs are applied in three situations: doorways, cross roads and line elements, such as dikes or quay walls. The probability of human error needs attention with these types of structures.

A dam is an example of a combined structure within the category hydraulic artefacts (Figure 3). Dams, like weirs, are designed for heading up water upstream of the dam. Dams are constructed for storage of water for irrigation, for the realisation of head difference for generation of electricity or for retention of flood water for protection downstream. Depending on the geological situation and the availability of materials three types are possible: earth dam, rock dam or concrete dam.

A dike is an example of a permanent immovable structure within the category earth structures (Figure 3). They are handmade soil bodies (Technical Advisory Committee on Water Defences 1998). The water retaining capacity is based on the dimensions and shape of the cross section. It derives stability for erosion by the use of special material. It must be ensured that there is sufficient strength of the core and the subsoil.

The matrix

The UFPC is a matrix in which both datasets are combined, giving an overview of which combinations between the two datasets are possible and which are less likely to become a success. The UFPC can be of help with the design of a new waterfront by a team of urban planners and flood controllers, especially during the primary design cycle. The UFPC gives inspiration with the help of urban images. It gives several visions of how a waterfront can look like. Urban planners can use these images for inspiration in the design of a waterfront. However, they can also use the UFPC to categorise their urban design. The matrix translates urban visions into technical possibilities; ergo the matrix shows how these visions can be realised. This will help the flood controllers in understanding the urban plans of the waterfront. By categorising an urban design, the urban planners can show the flood controllers the technical feasibility of their design. Furthermore, this is also useful for the urban planners them selves. It will help them as well in realising if their urban plans are technically feasible. The use of the UFPC can also be initiated through the need to improve the flood defence in a city. Improving the flood defence with explicit refurbishment of the waterfront is bound to result in a more harmonious waterfront than improvement of the flood structures alone. Again, a team of urban planners and flood controllers might benefit from the use of the UFPC during the primary design stage.

The UFPC is not only useful in the design process of a new waterfront; it can also be of help with the alteration of an existing waterfront. By analysing which flood retaining structures are already present at the waterfront, an indication can be given about the amount of work it will take to alter the waterfront within one of the presented urban images. Some urban images are more likely to fit in the current urban structure of a waterfront than others.

Figure **4** shows a fragment of the UFPC matrix. In this fragment, stop logs, a slender retaining wall and a dike are shown of the flood retaining structures; an urban dike, a super quay and a water building are shown of the urban images. A indicates that a combination is fruitful, a indicates that a combination is possible but not preferred, and a indicates that a combination is not a success and must be avoided. For instance, a design within the urban image 'water building' is difficult to construct through the use of a dike; a quay wall has more potential. Another example is a design within the urban image 'urban dike'. This vision can be realized through the use of a dike but also through a combination of a quay wall and a dike. Stop logs are also possible, but due to the probability of human error this is not preferred. A dike is preferred in this case.

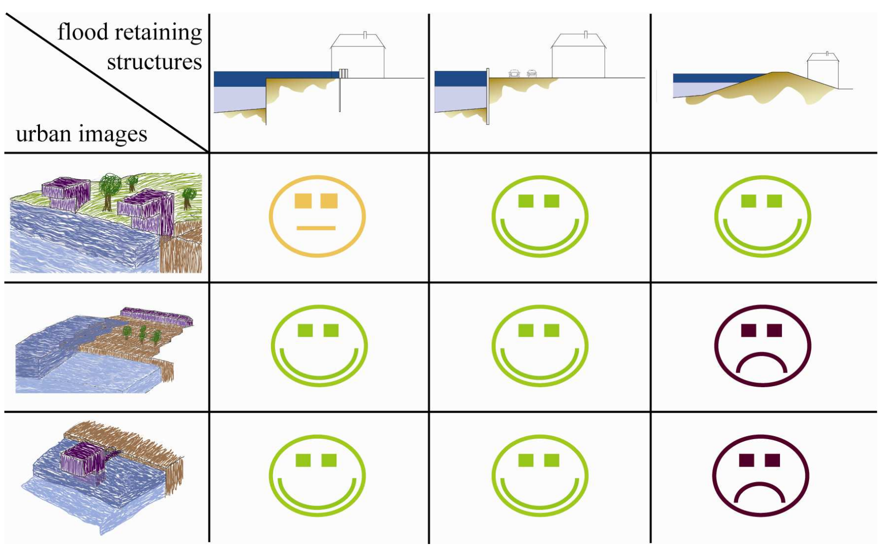


Figure 4: Fragment of the Urban Flood Protection Chart

EVALUATION OF THE UFPC DECISION TOOL

The Urban Flood Protection Chart (UFPC) was developed to contribute in realising a harmonious riverfront, for both urban planners and flood controllers. The question is therefore if the UFPC has met the stated requirements earlier. The UFPC provides a broad overview of flood retaining structures which ensures the safety of the waterfront, and hinterland, against floods. Hence, river cities can be preserved and protected against floods. Due to the incorporation of urban images it is also possible preserve or increase the quality of a riverfront. The combination of urban images and flood retaining structures is the strength of this decision tool. With the use of keen design sufficient space is possible for both improvement of flood structures and refurbishment of the waterfront. Remark on this decision tool is that the use of flood structures with a small number of failure mechanisms is hard to meet. Combining urban functions and flood protection is bound to result in rather complex multifunctional structures. This shows that it is impossible to meet all requirements; concessions on both sides are still needed. The rate of success of achieving a harmonious riverfront does not solely depend on the UFPC. Willingness and the actual conditions at the waterfronts are important factors. However, the UFPC is still a decision tool which helps in the process in achieving this harmonious riverfront; thus can be very useful.

CONCLUSIONS

The objective of this paper was to develop a decision tool which can contribute in realising a harmonious riverfront from both urban planning and flood control point of views. More specific: How could the friction between urban planners and flood controllers be solved in a more practical way, taking the AFD concept as point of departure? This has been realised through the development of the Urban Flood Protection Chart (UFPC), meeting as much requirements as possible. The UFPC is a matrix in which two datasets are combined: the dataset urban images and the dataset flood retaining structures. The matrix gives an overview of which combinations between the two datasets are possible and which are less likely to become a success. The UFPC can be of help with the design of a new waterfront, or an alteration of the existing waterfront, by a team of urban planners and flood controllers, especially during the primary design stage. The UFPC gives inspiration in the design process, it gives insight in each other fields and it achieves mutual understanding. Hence, it contributes to the process of decreasing the difficulties in improving the flood protection structures and the refurbishment of the urban waterfront in the shared realm.

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