Cost-benefit analysis to select the optimal flood protection strategy along the Scheldt

L. De Nocker[1], S. Broekx[1], I. Liekens[1], D. Bulckaen[2], S. Smets[2], J. Gauderis[3] & W. Dauwe[4]
[1]*Flemish Institute for Technological Research (VITO), Boeretang, Mol, Belgium*
[2]*Internation Marine and Dredging Consultants (IMDC), Belgium*
[3]*Resource Analysis (RA), Belgium*
[4]*Flemish Waterway Administration (AWZ), Belgium*

Abstract

The Scheldt estuary is a unique tidal estuary. The river originates from France and flows through Belgium and the Netherlands. The tide creates important flood risks in the Flanders region, including for the city of Antwerp. The Flemish government wants to update its flood protection policy, based on a cost-efficient reduction of risks of flooding and taking into account sea level rise. Against this background, the Flemish Waterway Administration commissioned a cost-benefit analysis of flood protection measures.

To this purpose a series of models of different scientific disciplines was integrated within a cost-benefit analysis framework. Results of cost-calculation, hydraulic, ecological and agricultural models were integrated in a cost-benefit model. Protection against flooding was evaluated on a risk based approach. This means that not only probabilities of flooding were considered but also possible damages sustained by flooding. Consequently a non-homogeneous level of security was allowed.

Measures evaluated include storm surge barriers nearby Antwerp or on tributaries, dike heightening and creating controlled inundation areas (floodplains). Constructing reduced tide areas which allows creation of new wetlands was also assessed. Benefits of nature development were taken into account when comparing costs and benefits of these measures. An optimal flood protection strategy was developed, and the optimal solution was tested using different kinds of uncertainty analyses for a wide variety of technical and economic parameters.

The analysis showed that cost-benefit analysis is a very useful approach to assist decision-making processes on designing flood protection measures and this approach is certainly applicable to other estuaries.
Keywords: cost-benefit analysis, flood protection.

1 Introduction

The Scheldt estuary is a unique tidal estuary. The river originates from France and flows through Belgium and the Netherlands. The tide creates important flood risks in the Flanders region, including for the city of Antwerp. In 1953 and 1976 the Netherlands and Belgium respectively knew very strong storm floods with devastating consequences. In 1977 the Belgian government created the Sigma plan for protecting the Sea Scheldt basin against storm tides. It consisted mostly of building dykes along the river side, next to a few controlled flood areas. The option to build a flood barrier downstream Antwerp was rejected in a cost benefit analysis in the early eighties.

Recent floods and sea level rise indicate that a new analysis is required, and new measures may be cost-efficient. Alternative measures include storm surge barriers nearby Antwerp or on tributaries, dike heightening and creating controlled inundation areas (floodplains). Constructing reduced tide areas which allow the creation of new wetlands was also assessed. Against this background, Flemish and Dutch governments commissioned a cost-benefit analysis of flood protection measures and nature development projects.

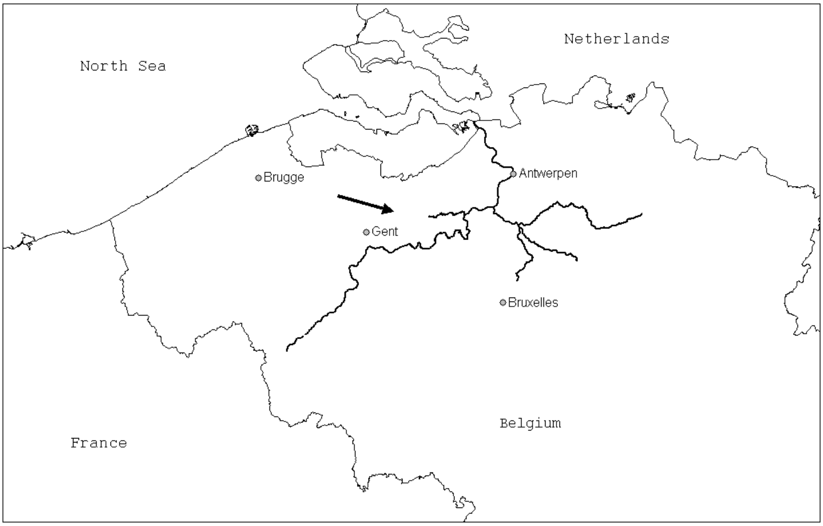

Figure 1: The Scheldt estuary.

2 Methodology

To determine the optimal flood protection measurements several models were combined in a multidisciplinary approach as illustrated in figure 2. A cost calculation model was used to determine comparable costs for the different flood protection measures and nature development measures. A meteo-hydrologic model predicted the impact of storms and floods with different chances of occurence, for scenarios with and without global warming and with and without flood protection measures. A GIS based damage model determined the damages following flooding or safety benefits of flood protection. Impacts of wetland creation on water quality were estimated with an external ecological model. These results were combined with an economic module to assess the environmental benefits on water quality and amenity in economic terms. This module builds on literature and specific CVM studies for impacts on amenity and non-use values. All results of previous models were integrated into a cost-benefit model to consistently compare costs and benefits of different policy options, including uncertainty analysis. (e.g. assessing relative impact of different assumptions related to sea level rise, economic growth and discounting) The time horizon for the model is 2100. This model calculates the cost-effectiveness of the selected measurements and based on these outcomes the measurement package is being optimised.

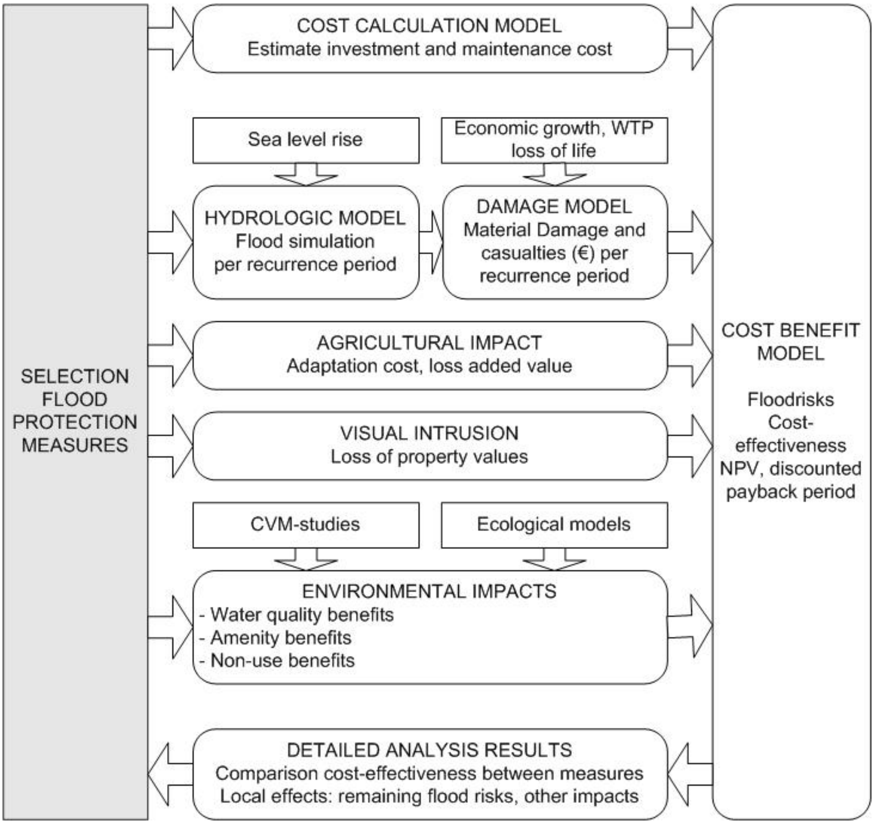

Figure 2: A set of multidisciplinary models in a cost-benefit framework.

3 Results

3.1 Flood protection measures

Four major alternative solutions to limit risks of flooding and improve the natural character of the river were studied. They were designed in a classical scheme i.e. starting from a design value for the protection value for the protection level against flooding (which is expressed as a probability of overtopping in the year 2050). No combinations were made between different alternative measures. These major solutions are:

1. a storm surge barrier downstream Antwerp
2. the use of the Eastern Scheldt as a controlled flood area, called the Overschelde
3. heightening and strengthening dykes and quay walls
4. creation of more space for the river by constructing floodplains, either controlled flood areas without nature development or reduced tide areas with nature development.

Building a storm surge barrier nearby Antwerp was already part of the original Sigma Plan but was rejected based on a cost benefit analysis. However, cheaper solutions which can also be applied on the Scheldt have been designed and constructed since then in the Netherlands. A decrease in cost and an increase in safety benefits due to sea level rise could make this measure a cost-effective solution. This measure is designed to withstand floods by storm tides for return periods of 10.000 years.

The "Overschelde" is a connection between the Western Scheldt and the Eastern Scheldt. The Eastern Scheldt is a large inlet connected with the North Sea. Tidal movements in this inlet can be retained by a large storm surge barrier. By closing this barrier at low tide, the Eastern Scheldt can be used to store water from the Western Scheldt. As the Eastern Scheldt is not connected with the Western Scheldt a canal of 4.2 km has to be constructed to use the Eastern Scheldt as a controlled flood area. This canal is called the Overschelde. Not only a canal is needed, but also a barrier to control the use of the Overschelde. As a canal width of 700 m is needed, this barrier is larger as a storm surge barrier at Antwerp. Costs will be very high but this project has safety benefits both in Flanders as in the Netherlands.

Dyke heightening can be applied further upstream. In theory, an infinite number of heights and combination of heights can be examined. For the top-down approach only one variant was considered. This variant is designed to withhold storm with a recurrence period of 2500 years in the year 2050. About 300 km of dykes have to be heightened to achieve this level of protection. According to the present state of the dykes and the available space, types of dyke heightening can differ.

Floodplains are located in low-lying uninhabited areas. By deliberately keeping the river embankments lower, a quantity of water from the high storm tide wave flows into the area surrounded by ring dykes. In this way, the propagating tidal surge is attenuated, thus reducing the flood risk in the upstream areas. The working of a Controlled Inundation Area (CIA) is illustrated in figure 3.

A variant of a CIA, which is also examined in the first phase, is a Reduced Tide Area (RTA). During high floods these areas operate as a CIA. During normal periods however, inlet sluices permit a reduced water level variation in the area, permitting the development of new marshes and mudflats. The areas are controlled because the tides in these areas are regulated by means of influx and efflux constructions in the dykes; they are reduced because the difference between ebb and flood inside such an area is smaller than for the river itself.

3.2 Cost benefit analysis

Building a storm surge barrier near Antwerp requires an investment between € 500 and 600 million and realizes the highest safety benefits in the Flanders region. A storm surge barrier has negative safety benefits in the Netherlands compared with the baseline scenario. When the barrier is closed during high tides, no water can be stored upstream from the barrier. Water levels in the downstream area (the Netherlands) rise. Other impacts are minimal. Net benefits until 2100 are € 340 million. Payback period is 41 years, which is lower than half the lifetime of the project (100 years). When more stringent parameters are applied in a worst case scenario, costs of a storm surge barrier are higher than it's safety benefits.

The Overschelde has by far the highest investment cost. With an estimate of € 1500 million this project is three times as expensive as a storm surge barrier. The Overschelde has however safety benefits in both Flanders and the Netherlands. These benefits are not sufficient to regain this huge investment. Other impacts are not considered, but are not relevant as net benefits until 2100 are negative even without these impacts.

Investment costs for heightening dykes to achieve a protection level of 1/2500 requires approximately half the investment of a storm surge barrier. Safety benefits are slightly lower than these from the barrier, but are comparable. A payback time of 27 years is shorter than this for a barrier. In worst case conditions costs outweigh safety benefits. Other impacts are not considered, but are very low compared to floodplains.

The alternatives with floodplains (both CIA and RTA) achieve the lowest protection level (1/1000) and consequently have the lowest safety benefits in Flanders. Some floodplains close to the border are able to reduce water levels on the Dutch part of the Scheldt and thus also realize safety benefits in the Netherlands. The effect is however much smaller than the effects of the Overschelde. Costs of the floodplains are much lower than dykes and total safety benefits are comparable. Net benefits are highest and the discounted payback time is the shortest. Even in the worst case scenario the payback times are considerably short.

Safety benefits of CIA's and RTA's are identical. Investment costs, however, differ slightly as more sluices are needed in RTA's to control the tides on a daily basis. Impacts on agriculture in RTA's are higher as agriculture no longer is possible in these areas, while in the case of CIA's it is still possible to use the area for low value crops. Nature development benefits of RTA's are substantial. In this first phase only regulation functions and recreational benefits are taken into account. Even without consideration of non-use values and production functions the alternative with RTA's has the shortest payback period.

4 Conclusions

A multi-disciplinary approach was designed to determine a package of measures that is able to safeguard the Scheldt estuary against flooding on a longer term. As effects were examined on a long term it was important to take effects of sea level rise into account when assessing flood risks. Alternative measures examined were storm surge barriers nearby Antwerp or on tributaries, dike heightening and creating controlled inundation areas (floodplains). Constructing reduced tide areas which allows creation of new wetlands was also assessed.

First results show that risks of flooding will increase significantly due to sea level rise. Due to this increasing risk complementary measures are needed along the river Scheldt to achieve an acceptable protection level. First results also showed that high cost measures which are designed to withstand floods by storm tides for return periods up to 10.000 years, are less favourable than the alternatives which achieve lower protection levels (1/1000). Their larger safety benefits do not outweigh their excess investment costs.

The analysis showed that cost-benefit analysis is a very useful approach to assist decision-making processes on designing flood protection measures. It shows that a careful assessment of all options and measures can allow one to get high safety benefits with very cost-efficient measures. This approach is certainly applicable to other estuaries.

Acknowledgements

This work was financed by Flemish government (LIN, AWZ Belgium, see www.sigmaplan.be) and profited from work for ProSes (see www.proses.be). The models gained from inputs and comments from many scientist including Ecosystem Management Research Group, University of Antwerp and Witteveen & Bos, from Central Planning Bureau, NL, and from many stakeholders that were involved in the decision making process for which this study was used.

References

[1] Barbier, E., Acreman M. en Knowler D., Economic valuation of wetlands: a guide for policy makers and planners, Ramsar, Switzerland, 1997.
[2] Defra, Flood and coastal defence, Project appraisal guidance FCDPAG 3 procedural guidance for operating authorities, 1999.
[3] De Nocker L., Broekx S., Liekens I., Maatschappelijke kosten-batenanalyse Overschelde als korte en/of lange termijnoplossing voor veiligheid tegen overstromen in Nederland en Vlaanderen, VITO, Boeretang 200 B-Mol Belgium, 2004.

[4] De Nocker L., Broekx S., Liekens I., Natte natuur in het Schelde-estuarium, een verkenning van de kosten en baten, CPB-VITO, Boeretang 200 B-Mol Belgium, 2004.
[5] Eijgenraam C, Koopmans C, Tang P, Verster A. Evaluatie van infrastructuurprojecten en leidraad voor kosten-batenanalyse, 2000.
[6] MAFF (Ministry of Agriculture, Fisheries and Food). FCDPAG5 Flood and Coastal Defence Project Appraisal Guidance, 2000, pp. 69.
[7] RA-IMDC-Vito (2004) Maatschappelijke kosten batenanalyse veiligheid tegen overstromen in het Schelde-estuarium, Conclusies op hoofdlijnen, 2004.
[8] Turner K, van den Bergh J, Söderqvist T, Barendregt A, van der Straaten J, Maltby E, van Ierland E. Ecological-economic analysis of wetlands: scientific integration for management and policy. Ecological Economics 2000; 35: pp. 7–23.
[9] Vanneuville W, Maeghe K, De Maeyer P, Mostaert F, Bogaert P. Risicobenadering bij waterbeheersingplannen, Methodologie en case study Denderbekken, 2002, pp. 73.