Quantifying multiple planning objectives of flood adaptation measures – a case study of Odense, Denmark

Quantification des objectifs multiples des mesures d'adaptation aux inondations urbaines - le cas d'étude d'Odense au Danemark

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RÉSUMÉ

L'implémentation de mesures d'adaptation aux inondations urbaines fait face à des barrières organisationnelles et financières. Nous quantifions et évaluons les objectifs des mesures d'adaptation aux inondations urbaines dans la perspective plus générale de l'aménagement urbain. En recadrant l'objectif "réduire les dégâts des inondations" dans l'objectif d'aménagement "améliorer les espaces urbains" par exemple, le but est de formuler les mesures d'adaptation en attirant les acteurs concernés. Nous analysons les études quantifiant les effets des mesures d'adaptation dans la littérature scientifique et dans les base de données et outils existants. En analysant des études à diverses échelles de temps et d'espace, nous améliorons la compréhension des indicateurs clefs. Nous appliquons les recherches préliminaires à un cas d'étude à Odense, au Danemark. Les résultats montrent que les objectifs dominants sont ceux qui visent à améliorer la qualité de l'air et la santé des habitants. Les résultats sont très sensibles au modèle d'agrégation et aux paramètres utilisés pour calculer les indicateurs. Ceci souligne l'importance de mieux comprendre les indicateurs pour ne pas sous ou sur estimer la contribution des mesures d'adaptations aux objectifs d'aménagement urbain.

ABSTRACT

It is difficult to implement urban flood adaptation measures due to organisational and financial barriers. We quantify and value planning objectives of urban flood adaptation measures in relation to urban planning. The purpose of doing so is to be able to frame adaptation projects to attract relevant stakeholders, e.g. by changing the framing from “reduce flood damage” to “improve urban areas”. Studies quantifying the effect of measures and primary valuation studies are searched for in literature, being electronic journal databases and existing tools and databases. We focus on studies that differ in time and space to get a better understanding of the indicators to improve our project estimates. We apply preliminary findings to a case study in Odense, Denmark. The results show that objectives of increasing air quality and physical health are dominating. The results show a high sensitivity to the initial input values used to calculate the indicator and to the aggregation method. This stresses the importance of understanding indicators better to not under- or overestimate the contribution of measures to the targeted planning objectives.

KEYWORDS

Flood adaptation, Indicators, Objectives, Urban planning, Valuation

1 INTRODUCTION

Spatial planning need to consider flood adaptation, and urban water management in general, on the same terms as other urban planning objectives. With space being a limited resource in cities and further limited with increasing urbanisation, space “takers” need to be multifunctional to be relevant (Fratini et al., 2012; Geldof and Stahre, 2004; Kuller et al., 2017; Madsen et al., 2018). Green and blue flood adaptation measures, for which different terms are used in literature (e.g. SUDS, WSUD, LAR, BGI), have gained increasing interest due to their multifunctional nature (Fletcher et al., 2015). Despite their multifunctional potential, implementation is still challenging, mainly due to financial and organisational barriers (Fratini et al., 2012; Geldof and Stahre, 2004; Kuller et al., 2017; Madsen et al., 2018). Skrydstrup et al. (2018) presented a way of overcoming these barriers. The study investigated planning objectives and their connection to stakeholders for both urban water management and urban planning. In this way, providing a framework for communicating and planning urban adaptation measures. As a next step, we now quantify and monetize these planning objectives so they can be compared to traditional costs, such as the investment of the strategy.

A vast amount of quantification and valuation studies exists, but they are rarely aimed at an urban context (Gómez-Baggethun and Barton, 2013). Additionally, studies rarely include both quantification and valuation, which might result in a mismatch between these two types of indicators (Chan et al., 2012). However, several tools relevant for quantification and valuation exists (e.g. BeST (Horton et al., 2015), The green infrastructure valuation toolkit (Green Infrastructure Valuation Network, 2013), The Value of Green Infrastructure (CNT, 2010)). While these tools are a good starting point, they are not directly related to stakeholders and their planning objectives in a Danish context.

This study aims to identify effect- and value indicators to assess the planning objectives of urban flood adaptation measures. The aim is to understand the spatial and temporal variation of indicators connected to planning objectives by identifying effects and values estimated in different contexts. Finally, the indicators are applied and tested in a Danish case study.

2 METHODOLOGY

2.1 Literature screening

We screen literature to identify effect- and value indicators to couple flood adaptation measures with planning objectives of urban water management and urban planning as identified in (Skrydstrup et al., 2018), but focus only on the social and environmental planning objectives (Table 1).

Table 1: A selection of planning objectives that will be connected to effect- and value indicators in this study. The objectives were identified in (Skrydstrup et al., 2018).

Objective	Description
Aesthetics	Ensure aesthetically pleasing strategies
Recreation	Access to and space for areas for recreational activities
Air quality	Maintain or increase air quality
Nuisance	Reduce urban heat island effect, wind- and noise levels in the city
Water quality	Ensure good water quality in surface- and groundwater
Nature & Biodiversity	Maintain, protect and increase nature areas
Sense of security (flooding)	Reduce risk of flooding to increase safety for citizens
Physical activity	Increase citizens incentive to be more physically activity
Crime	Reduce crime in the area

We search for studies that quantify the functions of measures (effect indicator) and studies putting a monetary value on it (value indicator). We search for literature in electronic journal databases (e.g. Web of Science, Google scholar), mine already existing tools (e.g. BeST (Horton et al., 2015)) and databases (e.g. TEEB (Van der Ploeg and de Groot, 2010)). We include peer-reviewed articles, other articles (only for qualitative connections), books and official reports. Primary studies in English from Europe, USA and Canada with an urban context and with a strong connection between urban flood adaptation measures and planning objectives are prioritized. Ultimately, we want to understand the variation in effects and

values, which is why we are looking for studies with spatial and temporal variation, and studies with variation in reference levels, i.e. starting point for the assessment (e.g. status of water quality). Data are categorized to ensure consistency and comparability.

2.2 Application

The indicators are applied to a case study in Odense, Denmark, to illustrate the application of indicators and the potential attainment of planning objectives. The objectives are expressed in Euro/year and can both be an economic benefit or a cost for a project. These benefits and costs might appear in different points in time, so to get a present estimate of the total value of the flood adaptation strategies, the annual cash flows need to be converted to Net Present Value (NPV) (e.g. (de Bruin et al., 2008)):

$$NPV = \sum_{t=0}^{T_{end}} \frac{B_t - C_t}{(1+r)^t}$$

Where B_t are the benefits for time period t, and C_t the costs for the same time period. T_{end} is the considered time period, e.g. 50 years. r is the discount rate and 3% is often used in Denmark for climate change adaptation projects (Damgaard et al., 2006). A NPV is calculated for each strategy for comparison.

3 RESULTS AND DISCUSSION

Gallus (2018) performed a similar analysis as suggested in this abstract on a case study in Odense. These results thus provide as showcase for the analysis expected by the time of the conference. The results were based on an assessment of flood adaptation measures for Dyrup. Dyrup has a catchment size of 503 hectares and consist of residential, commercial and public buildings. Besides climate change adaptation, it was assumed that no urban development would take place in the area within the 50-year time horizon. A three-hectare green area in the centre of Dyrup was chosen as location for the implementation of the adaptation measure. Three strategies were analysed, where the only difference between them was the design of the land cover, i.e. the hydraulic capacity was the same.

The quantified objectives were to increase physical health, reduce urban heat island (UHI) effect, increase air quality, reduce noise and increase recreation in the area. Figure 1 shows the resulting NPV of the objectives relative to baseline for three potential strategies, considering a 50-year time horizon. Results show that air quality and physical health are dominating for Case A, and only physical health for Case B. The difference between Case A and Case B is the use of values for quantifying air quality and how recreation and health are aggregated. Results illustrate the importance and sensitivity of applied values and how they are calculated, as air quality improvements becomes insignificant and physical health benefits halved for Case B. Furthermore, it shows the trade-offs when changing an already green area into another green design, and thus illustrates the importance of the design and the area of implementation for obtaining the targeted objectives. In this specific case, trees are playing a big role as they mitigate air pollution, but also take up space for other activities that might increase people's incentive to move.

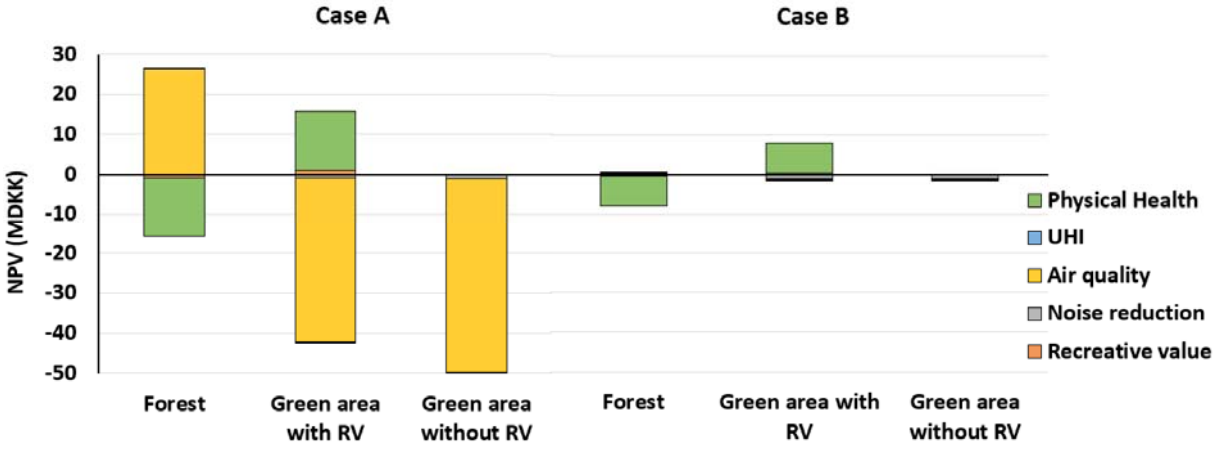

Figure 1: NPV of considered planning objectives for Dyrup in Odense, Denmark. Results show that only physical health and air quality is dominating. The difference between Case A and Case B are values of air quality and aggregation method for physical health and recreation. RV = Recreational Value.

The interpretation of results using these types of indicators should be done carefully. Firstly, it is not

known if air pollution or inactive residents are a current or expected problem in the area. For example, air pollution is difficult to evaluate because there is a non-linear relation between peoples willingness-to-pay and change in air quality. To not under- or overestimate the value, it is essential to know the reference level for the primary valuation study, the current air quality in the assessment area and the expected change. However, the lack of local studies makes is necessary to apply international and/or national studies as done in the study by Gallus (2018). This field is further challenged by the gap in studies quantifying climate change adaptation measures contribution to planning objectives. It is therefore necessary to understand which elements of flood adaptation measures contribute to objectives and how their effect and values vary with the urban context.

CONCLUSION

Quantification and valuation of planning objectives for flood adaptation measures are important for their implementation in urban areas. The design of measures and the context of their implementation are central for their contribution to urban planning objectives, but their relation to flood adaptation measures are not well understood. This stresses the importance of assessments that accounts for local conditions by taking into account a range of configurations from literature. This will provide better estimates of urban flood adaptation measures contribution to planning objectives. These aspects are the subject of our on-going work.

LIST OF REFERENCES

Chan, K.M.A., Satterfield, T., Goldstein, J. (2012). Rethinking ecosystem services to better address and navigate cultural values. *Ecol. Econ*. 74, 8–18.

CNT (2010). The Value of Green Infrastructure - A Guide to Recognizing Its Economic, Environmental and Social Benefits. Center for Neighborhood Technology, American Rivers.

Damgaard, C., Strandmark, L., Heideman, R., Nielsen, T., Emborg, L. (2006). Recommended methodology in relation to socio-economic assessments of adaptation to climate change. (In Danish: Metodemæssige problemstillinger i forbindelse med samfundsøkonomiske vurderinger af klimatilpasningstiltag). Copenhagen, Denmark.

de Bruin, K., Ierland, Van, E., Dellink, R. (2008). Some basics on cost benefit analysis in the context of adaptation to climate. Environmental Economics and Natural Ressources group, Wageningen University.

Gómez-Baggethun, E. and Barton, D. N. (2013). Classifying and valuing ecosystem services for urban planning. *Ecol. Econ*. 86, 235–245.

Fletcher, T.D., Shuster, W., Hunt, W.F., Ashley, R., Butler, D., Arthur, S., Trowsdale, S., Barraud, S., Semadeni-Davies, A., Bertrand-Krajewski, J.L., Mikkelsen, P.S., Rivard, G., Uhl, M., Dagenais, D., Viklander, M. (2015). SUDS, LID, BMPs, WSUD and more – The evolution and application of terminology surrounding urban drainage. *Urban Water J*. 12, 525–542.

Fratini, C.F., Geldof, G.D., Kluck, J., Mikkelsen, P.S. (2012). Three Points Approach (3PA) for urban flood risk management: A tool to support climate change adaptation through transdisciplinarity and multifunctionality. *Urban Water J*. 9, 317–331.

Gallus, E. (2018). Co-benefits of climate change adaptation in Odense. Department of Environmental Engineering, Technical University of Denmark. Kongens Lyngby, Denmark.

Geldof, G.D., Stahre, P. (2004). The interaction between water and society. *Enhancing Urban Environ. by Environ. Upgrad. Restor.* 381–394.

Green Infrastructure Valuation Network (2013). Building natural value for sustainable economic development: The green infrastructure valuation toolkit user guide.

Horton, B., Digman, C.J., Ashley, R.M., Gill, E. (2015). BeST (Benefits of SuDS Tool): W045c BeST - Technical Guidance.

Kuller, M., Bach, P.M., Ramirez-Lovering, D., Deletic, A. (2017). Framing water sensitive urban design as part of the urban form: A critical review of tools for best planning practice. *Environ. Model. Softw*. 96, 265–282.

Madsen, H.M., Andersen, M.M., Ryggard, M., Mikkelsen, P.S. (2018). Definitions of event magnitudes, spatial scales, and goals for climate change adaptation and their importance for innovation and implementation. *Water Res*. 144, 192–203.

Skrydstrup, J., Madsen, H.M., Löwe, R., Thorén, H., Arnbjerg-Nielsen, K. (2018). How to make our models relevant for decision-makers by using stakeholder analysis?, in: *Proceedings of the 11th International Conference on Urban Drainage Modelling*. Palermo, Italy, pp. 1106–1109.