HELMHOLTZ
ZENTRUM FÜR
UMWELTFORSCHUNG
UFZ

UFZ Discussion Papers

Department of Economics

8/2015

Ecosystem services in German infrastructure planning – a case study of the projected Lower Weser deepening

Nils Droste, Jasper N. Meya

May 2015

Publisher:
Helmholtz-Zentrum für Umweltforschung GmbH - UFZ
Permoserstr. 15
04318 Leipzig

ISSN 1436-140X

Ecosystem services in German infrastructure planning – a case study of the projected Lower Weser deepening

This article is currently under review in Journal of Environmental Planning and Management

Nils Droste[a,b], Jasper N. Meya[c]

[a] *Department of Economics, Helmholtz Centre for Environmental Research – UFZ, Department of Economics Permoserstr. 15, 04318 Leipzig, Germany, nils.droste@ufz.de*

[b] *Faculty of Law and Economics, Martin-Luther University Halle-Wittenberg, 06099 Halle (Saale), Germany*

[c] *Faculty of Mathematics and Computer Science, University of Bremen, 28334 Bremen, Germany*

Abstract: We study the incorporation of ecosystem services in German water infrastructure planning exemplified by a projected deepening of the Lower Weser river channel. Therefore, we recalculate the project's benefit-cost ratio by integrating the monetary value of changes in different ecosystem services: i) the restoration costs of a planned mitigation measure for a loss in fresh water supply for agricultural production in the estuary, ii) costs of loss in habitat services by transferring the willingness to pay between a contingent valuation study to the area assessed in the environmental impact assessment, and iii) the benefits of emission savings induced by more efficient shipping taking a marginal abatement cost approach. We find that the inclusion of monetary values for ecosystem service changes leads to a substantial drop in the benefit-cost ratio and consequently argue for a reform of the standard to facilitate more complete welfare assessments.

Keywords: ecosystem services – cost-benefit analysis –infrastructure planning – river deepening – Germany

1. Introduction

The Weser river in North-West Germany has been deepened several times. Medieval agricultural expansion led to soil erosions that sanded the Weser and larger trade ships could no longer navigate to the port of Bremen city. In the late 19th century the first river dredging re-established navigability for ships of up to 5 meter draft (Franzius, Franzius, and Rudloff [1894] 2010). For the hanseatic city of Bremen regaining access to important trade routes likely yielded substantial welfare gains. But the deepening and straightening was not without external costs. As a consequence of the increased flow velocity and tidal range bed erosion had to be regulated by artificial weirs and dykes (Franzius, Franzius, and Rudloff [1894] 2010). Since then both the Lower Weser from Bremen to Bremerhaven and the mouth to the North Sea, the so called Outer Weser, have been dredged several times to improve navigability (Wetzel 1988). Alterations of the river flow regime led to increased tidal ranges from around 0.2 meters in 1880 to 4.1 meters today in Bremen-Oslebshausen and require protective measures (Schuchardt et al. 2007).

Currently, another deepening, an ‘adaptation of the Weser channel to developments in shipping traffic’ is planned (WSV 2011). The planning has been challenged before the Federal Administrative Court. The concerns mainly refer to environmental consequences caused by dredging and an altered flow regime (Ekardt & Weyland 2014). The case has been referred to the European Court of Justice asking whether the planning is in accordance with the no deterioration rule of the EU Water Framework Directive (ibid). Assuming diminishing marginal utility of further infrastructure measures and increasing marginal costs through decreasing environmental quality one might ask whether it still yields welfare gains to deepen the river further.

According to the German legislation all federal transportation infrastructure developments, such as the Weser channel deepening, have to “serve the common welfare” (BMVBW 2003a) and are therefore subject to economic feasibility studies by means of cost-benefit analysis (CBA) (ibid.). In order to fully access the effect on social welfare *all* related costs and benefits should be assessed and integrated into the CBA (Hanley & Barbier 2009). This should include gains and losses in ecosystem services as the Millennium Ecosystem Assessment (2005) and The Economics of Ecosystems and Biodiversity (TEEB 2010a) highlight the importance of ecosystem services for human wellbeing. In contrast, the CBAs conducted as part of the Federal Transportation Infrastructure Plan (Bundesverkehrswegeplan - BVWP) do not account for environmental effects beyond a general proxy for those measures legally required by impact mitigation regulation under German nature protection law.

Despite the growing literature on ecosystem services hardly any attempts have been made to account for their functions in German infrastructure legislation, which is the main area of applications of CBAs in Germany. One main exception are Petry and Klauer (2005), who extensively review the BVWP with respect to environmental valuation. Among other results, they conclude, that the current state of the art monetisation of environmental effects is not sufficiently reflected in the current BVWP. This clearly results in a likelihood of underestimating environmental effects. Zabel (2011) discusses the CBA for the Saale river channel adjustment, highlighting the importance of including environmental effects and correcting the existing CBA in terms of investment cost, loading projections and emission savings, which already substantially alter the outcomes in terms of benefit-cost ratios.

We add to this research by introducing a way of integrating ecosystem services based on existing information from the mandatory environmental impact assessment, by taking cost of a man-made substitute into account, identifying a systematic bookkeeping bias, and by discussing the monetary valuation of emission savings. This is relevant in several respects: When the values of ecosystem services affected are of relevant magnitude basing investment decisions on CBA’s, neglecting ecosystem services leads to an inefficient allocation of public spending. Furthermore, this identifies an “economic gap” (Petry and Klauer 2005, 98) between the scientific debate on ecosystem service valuation and actual implementation.

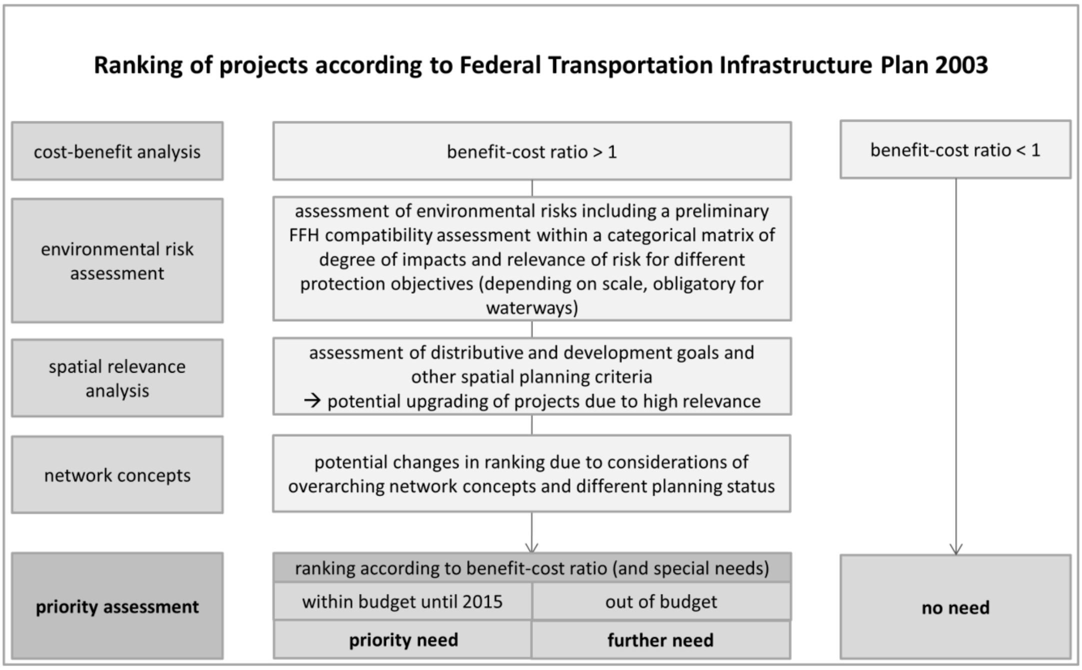
In Section 2 we elaborate on the methodology and role of CBA in the Federal transportation Infrastructure Plan. Turning to the case of the Lower Weser deepening in Section 3 we provide exemplary monetary valuations of changes in ecosystem services incurred by a further deepening in order to contrast the original CBA with an ecological extended one. In Section 4 we discuss limits and assumptions of our approach to integrated ecosystem services. Finally, Section 5 concludes and proposes open questions for future research.

2. Critical review of the German federal infrastructure planning process

In this section, we review the methodology and decision making process of the 2003 Federal Transportation Infrastructure Plan (BVWP) regarding the valuation of ecosystem services and the classification of maintenance cost.

The 2003 BVWP has the goal to steer public investments in a way that maximises social welfare (BMVBW 2003b). It has been generated by an integrated assessment across different carriers of transportation. Based on scenario planning and traffic prognosis (ISL et al. 2000; PLANCO 2005) it plans infrastructure investments for about 10 years. The Ministry of Transportation assesses proposed infrastructure developments mainly according to the monetary benefit-cost ratio, which is subject to public budget constraints, federal financial planning, and considers non-monetary criteria of spatial relevance and environmental risk (BMVBW 2003b; Petry and Klauer 2005). A consultation of Ministries, traffic associations, and federal states completes the overall planning to finally enact the BVWP by legislative procedures (Petry and Klauer 2005). The assessment criteria and methodology for the ranking within the BVWP have a central role within the overall planning procedure since they set priority for all following administrative implementations.

Figure 1: Schematic representation of the planning procedure within the 2003 Federal Transportation Infrastructure Plan (adapted from Petry and Klauer, 2005, p. 49)



Cost-benefit analysis (CBA) has a central role within this overarching decision making process. Figure 1 displays the combination of the partial assessments as a basis for assessing the overall priority of projects (Petry and Klauer 2005). Classes of needs are 'priority needs', 'further needs' or 'no needs' and are mainly defined by their benefit-cost ratio. By the structure of the administrative planning algorithm the benefit-cost ratio is the most important measure. It is the only criterion that will exclude projects from being pursued if the benefit-cost ratio is below one (BMVBW 2003a). A high spatial relevance can lead to upgrades within the priority ranking. A very high environmental risk e.g. through damage of protected areas does not result in downgrading or exclusion. Such risk requires further assessments of avoidance and mitigation potentials.

The aim of the cost-benefit analysis is to assess the economic welfare effects measured in monetary terms that facilitate a comparability of different consequences of the project – including external effects (BMVBW 2003b). Benefits are assessed in nine different categories such as decrease in transport cost or spatial benefits such as increase regional employments. Environmental benefits are only assessed in terms of reduction of noise and airborne emissions. Moreover, cost components are composed by a single factor representing investment costs which does not explicitly recognise ecosystem services or losses in environmental quality (Petry and Klauer 2005). Changes in ecosystem services are only implicitly included through impact minimizing and compensation measures for residual environmental impacts (BMVBW 2003b).

By neglecting environmental cost the BVWP framework stands in stark contrast to the concept of total economic value (Hanley & Barbier 2009; Pearce & Turner 1989), which includes changes in several value categories ranging from direct use values, to indirect use values, to option values, to existence values. The monetary value of these benefits from ecosystems and their services should inform public decision making (Russi et al. 2013; TEEB 2010a). Since many of these values are not traded, a market price becomes unavailable. In such case their monetary value can alternatively be estimated by either the willingness to accept or the willingness to pay assessed by revealed or stated preferences (Hanley & Barbier 2009; TEEB 2010b). In case of losses cost based approaches such as avoided cost, replacement cost, mitigation or restoration cost methods can provide estimates for the monetary value of losses in ecosystem services (TEEB 2010b).

The central decision variable in the infrastructure planning process is the benefit-cost ratio, which is calculated based on present values of annual benefits and cost[1]. This measurement is sensitive to the classification of cost and benefits. However,

[1] According to the current legislation (BVWP 2003) costs and benefits are measured in present values with a base year 2000 and prices of 1998. The discount rate is 3 per cent. For

a decision rule should be independent of whether costs are accounted for as negative benefits and vice versa (Pearce et al. 2006). This is in particular relevant, as in the BVWP increased maintenance costs are accounted for as negative benefits. The classification of maintenance costs (x) as benefits (B) biases the benefit – cost (C) ratio towards greater economic profitability because

$$\frac{B-x}{C} > \frac{B}{C+x} \tag{1}$$

for positive values of x. Thus, using a benefit-cost ratio as decision variable[2] in combination with the classification of maintenance cost as negative benefits results in an increased benefit-cost ratio. Even though this does not challenge the positive benefit-cost ratio of an individual project, it leads to a biased ranking of infrastructure projects and consequently to an inefficient allocation of public spending.

Summing up, despite the claim of estimating welfare effects the current public transport infrastructure legislation does not explicitly account for changes in ecosystem service provision and hence does not constitute a complete welfare assessment. Together with the classification of increased maintenance costs as negative benefits this tends to result in a substantial overestimation of the profitability of public infrastructure investments. The currently developed BVWP 2015 does differ in this respect and will not explicitly include environmental costs (Intraplan et al. 2014, chap.2.11).

---

waterway infrastructure investments on river and canal beds a use value over 100 years is assumed (BMVBW 2003b, p.99).

[2] In contrast to benefit-cost ratio a benefit-cost difference would be independent of the classification of cost and benefits.

3. Integrating ecosystem services into cost-benefit analysis of the projected Lower Weser deepening

In the following we discuss the original cost-benefit analysis (CBA) that led to the inclusion of the Lower Weser deepening as a high priority project in the 2003 Federal Transportation Infrastructure Plan (BVWP) (PLANCO 2002)[3]. We furthermore monetise changes in affected ecosystem services in order to re-estimate the benefit-cost ratio for the Lower Weser deepening.

3.1 Original cost-benefit analysis

The first planning procedures for a further deepening of the Weser were initiated in the early 2000's. PLANCO was commissioned by the Federal Ministry of Transportation to provide a CBA for the projected river deepening (PLANCO 2002).

According to PLANCO (2002) a deepening of the Weser river channel includes the following annual benefits: Improvements in *shipping capacity utilisation* yield yearly benefit (€^{1998} 6.54 million)[4] because a deeper channel allows to discharge less cargo before entering the Weser, so that the number of ships required and hence transport costs would be reduced. *Time savings* in waiting times incurred by tidal phases would accrue benefits because the tide related time frame to excess ports would be extended for larger ships (€^{1998} 0.05 million). The channel deepening causes *increased maintenance cost*s (€^{1998} -1.99 million) due to a rising need for maintenance dredging, that are accounted for as negative benefits (PLANCO 2002). *Regional employment*

---

[3] There is an additional and partly revised CBA (PLANCO 2009). In comparison to the original CBA it is even less explicit in its assumptions and methodology which makes it harder to reproduce.

[4] Monetary values are converted to €^{1998} throughout the text using the annual consumer price indices for Germany (Statistisches Bundesamt 2014).

increases during the phase of deepening the Lower Weser (€^{1998} 0.01 million). *CO_2 and NO_X emissions* are abated, as better used capacities require less ships and thereby less fuel per transported ton of cargo. It constitutes the largest annual benefit (€^{1998} 8.64 million) for deepening the Lower Weser in the original CBA (PLANCO 2002). Finally, the *advancement of international trade* improves international labour division and is thereby beneficial in welfare terms (BMVBW 2003b). It is calculated as a ten per cent bonus of the savings in operational costs (€^{1998} 0.66 million). The only considered cost are *investment cost*, estimated with a total €^{1998} 15.34 million, with 57 per cent accruing in the first year and the remainder being equally distributed over the subsequent years of activity (2011-2014) (PLANCO 2002). Though not explicitly stated, this includes a lump-sum of compensation measures for environmental effects (Petry et al. 2005). The projected Weser deepening was given a 'high priority' in the BVWP 2003, since based on these figures a benefit-cost ratio of greater than 26:1 was estimated (PLANCO 2002, 2009).

3.2 Valuation of affected ecosystem services

Subsequently, we monetise two main losses in ecosystem services and adjust the prices for a reduction in greenhouse gas emissions in order to illustrate the magnitude of the effects on the environment caused by the Weser channel adjustment.

Firstly, one main impact of the Weser deepening is an associated loss in provisioning fresh water quantities (Russi et al. 2013) for agricultural production in the region. Dredging results in a stronger upstream intrusion of brackish waters into the estuary and an increased salinity (BAW 2004; Johnston 1981; Luo et al. 2007; National Research Council Marine Board 1985). This changes the fresh water supply left the Lower Weser, i.e. in a region called Wesermarsch (IDN 2008). The farmers in the region use the system of canals and ditches to water their cattle and land – this is a *provisioning ecosystem services* that would be affected by a dredging of the Lower Weser. The ‘Generalplan Wesermarsch’ has been generated to improve the fresh water supply in Wesermarsch. Administratively, it is a different project and the relation between the two is challenged politically. It has been argued that the planning for Wesermarsch is not meant to compensate for damage of the planned Lower Weser deepening but for damages done by former deepening (Niedersächsischer Landtag 2012). Assuming increasing marginal costs, the environmental damage of former channel deepening would be a conservative estimate of the environmental damage of the currently planned deepening. Hence, we assume that the costs for the plan can be used as proxies for the restoration costs of losses in provisioning fresh water ecosystem services for agricultural production. The two federal states of Lower Saxony and Bremen budgeted $€^{2011}$ 50 million for the compensation measure. A study commissioned to elaborate the plan estimated $€^{2011}$ 86.7 million as the most cost-efficient measure (NLWKN 2011), whilst the ongoing political discourse has stated that costs may raise up to $€^{2011}$ 120 million (Niedersächsischer Landtag 2012). We use the $€^{2011}$ 86.7 million as a best guess estimate, the already political guarantied sum as a lower bound and the maximal mentioned cost as upper bound estimates to indicate the range of uncertainty. We assume that the costs accrue constantly over the 14 years (NLWKN 2011) of planning and implementation, which gives an average yearly flow of $€^{1998}$ 6.19 ranging from 3.57 to 8.57 million.

Secondly, *habitat and gene pool protection services* are affected by the dredging activities in the river bed. The environmental impact assessment (GfL et al. 2006a) finds an overall ‘significantly negative‘ impact on different ecosystems along the river and its tributaries that has to be mitigated or compensated. The landscape conservation plan that specifies the measures (GfL et al. 2006b) finds a total of 109.8 hectares subject to different types of encroachments by dredging. According to the value of the affected ‘subject of protection’ (German: “Schutzgut”) (Rundcrantz & Skärbäck 2003) and the expected loss of value measured in categories, different factors apply for different types of encroachments (Wende et al. 2005; GfL et al. 2006b). When this is factored in, the landscape conservation plan estimates a compensation need for permanent damages of 32.9 ha (GfL et al. 2006b). The area for planned compensation measures to offset the losses along different subjects of protection is 61.16 ha (GfL et al. 2006b). We take the area of creditable compensation measures as a best guess estimate (61.16 ha), and use the area of compensation need (32.9 ha) and actual encroachment (109.8 ha) as lower and upper bound estimates. The cost of the compensation measures, estimated as €^{1998} 4.0 million (WSA Bremerhaven, personal communication, 2014) in total, would only resemble the loss of ecosystem services, if the compensation measures were perfect substitutes, which is generally not the case (Petry and Klauer 2005). Alternatively, welfare effects could be measured by how people value these ecosystem services. Therefore, we estimate the value of the losses in habitat services by a benefit transfer from a contingent valuation study for the willingness to pay (WTP) of households of the Elbe region for a restoration of a natural flood plain (Meyerhoff 2002). Inhabitants of Elbe, Weser and Rhine regions were shown a bundle of measures to protect habitats and biodiversity at the Elbe, mainly the restauration of 15000 ha flood plains through dyke relocation, extensive agriculture and species protection measures. Meyerhoff (2002) elicits under the most conservative assumptions (exclusion of protest votes, correction of embedding effect and 2.5% reduced arithmetic mean) a yearly WTP of €^{2001} 108 million, which we scale down to the area effected and the number of households in the Lower Weser region. Here, we make the very conservative assumption (Horowitz & McConnell 2002) that WTP equals willingness to accept. This yields annual cost through the loss of the habitat and species protection of €[1998] 2.07 ranging from 1.11 to 3.71 million.

Thirdly, the planned channel adjustment would allow larger ships to transport the same amount of cargo and thereby use less fuel per transported ton of cargo. The savings in fuel lead to emission abatement. This constitutes a benefit through *mitigation of airborne emissions*[5] since damages are avoided (BMVBW 2003b). The BVWP method[6] uses average abatement cost with values being high compared to recent estimates[7] (Kuik et al. 2009; Umweltbundesamt 2012a). We follow the approach of the German Federal Environmental Agency assuming that the national political mitigation target in the BVWP (BMVBW 2003b)(BMVBW, 2003b) equals limiting global warming to a 2 C° temperature increase (Umweltbundesamt 2012a; Wille et al. 2012). However, with current international mitigation efforts corresponding to scenarios of 550 to 650 ppm CO_2eq by 2100 (Edenhofer et al. 2014), we assume a stabilisation around 500 ppm CO_2eq, which is still likely to keep global temperature increase below 2°C (IPCC 2014). Estimates on marginal abatement cost are available from Kuik, Brander, and Tol (2009), who conducted a meta study based on 62 estimates from 26 different models from the EMF-21 and IMCP modelling fora. Accordingly, marginal abatement cost for stabilising atmospheric greenhouse gas concentration at 500 ppm CO_{2eq} are predicted as 66.00 €[2005]/tCO_2eq for 2025 (with 36.50 and 119.40 being lower and upper bounds, respectively) and 133.90 €[2005]/tCO_2eq for 2050 (ranging from 79.40 to 226.00)

[5] Lieken, Broekx, and De Nocker (2013) consider water quantity available for transportation an ecosystem service. Deepening the channel may hence yield benefits through an increased water flow that allows for more efficient shipping.

[6] Emissions are valued through average abatement cost to reach 80% emission reduction target in 2050, approximated as 205 €[1998]/t and 365 €[1998]/t for CO_2 and NO_X emissions, respectively (BMVBW 2003b). These estimates go back to studies by Jochem et al. (1997) and Masuhr et al. (1991).

[7] In fact, beyond the price also the quantity of emission savings appears to be highly uncertain. In the revised CBA from PLANCO (2009) the benefits from emission reduction drop from the originally reported €[1998] 175.25 million to just €[1998] 21.4 million.

(Kuik, personal communication, 2014)[8]. Marginal abatement cost are highly convex in the rate of emission control (IPCC 2007; Kuik et al. 2009) and are expected to rise over time. Hence, we assume marginal abatement cost to increase more than linear over time. Assuming zero abatement cost in 1987 (the reference point in the BVWP 2003), we calibrate a second degree polynomial to the mentioned data points. This gives yearly benefits of abated emissions of €^{1998} 1.63 million in 2015 (with a lower bound of 0.86 million, and a higher bound of 3.05 million) and €^{1998} 14.58 million in 2115 (with a range from 9.48 to 22.09 million)

3.3 Ecological extended cost-benefit analysis

Next, we adapt the original CBA for the Lower Weser river channel adjustment to our three main points of criticism: integrating ecosystem services, valuing carbon emissions with marginal abatement cost based on recent studies and correcting the bookkeeping bias.

We find a present value of the habitat and gene pool protection service and the provisioning ecosystem service of €^{1998} 47.18 (from 25.38 to 84.71) million and €^{1998} 44.90 (25.89 up to 62.15) million, respectively. Each of these figures is on the lower bound already twice as high as the investment cost, highlighting the relative importance of environmental related cost compared to the pure financial cost. Moreover, we recalculate emission reductions due to more efficient shipping with marginal abatement cost. Leaving the value for NO_x emission untouched this gives benefits from emission reductions of €^{1998} 97.69 (ranging from 61.19 to 158.91) million, with the higher bound still being below the original figure. This illustrates, that due to discounting and the long

[8] Note, that marginal abatement cost strongly depend on the stringency of the long term political target (Edenhofer et al. 2014; Kuik et al. 2009) and results hence rest on the assumed stabilisation target with both nationally and globally less stringent climate goals resulting in substantially lower abatement cost.

time horizon it makes a substantial difference, whether average or marginal abatement cost are considered.

Recalculating the original CBA with these figures and classifying maintenance cost as cost, the benefit-cost ratio drops from 26.12 to 1.71 (from 1.05 to 2.99) (see Table 1). Hence, the benefit-cost ratio appears to be very sensitive to our amendments and this sensitivity appears to be relatively robust to the considered uncertainties in the ecosystem service valuation.

Table 1: Original and ecological extended cost-benefit analysis, present values in million €^{1998}

	Original CBA[9]	Ecological extended CBA
Benefits		
benefits from improved shipping capacity utilisation	132.74	132.74
benefit from time savings	1.04	1.04
increased maintenance cost	-40.44	
regional employment during investment phase	0.28	0.28
benefits from abated CO_2 and NO_X emissions	175.25	97.69 [61.69; 158.91]
benefits from advancing international trade	13.48	13.48
sum of benefits	282.35	245.22 [208.73; 306.44]
Costs		
investment costs	10.81	10.81
increased maintenance costs		40.44
loss of habitat and gene pool protection service		47.18 [25.38; 84.71]
loss of freshwater provisioning service		44.90 [25.89; 62.15]
sum of costs	10.81	143.34 [102.53; 198.10]
benefit-cost ratio	26.12	1.71 [1.05; 2.99]

Lower and upper bounds are reported in square brackets

[9] Values are reproduced by the authors based on annual figures from PLANCO (2002). There remains a difference of less than 2 per cent compared to the CBA by PLANCO.

4. Discussion

In this section, we discuss the limits and implications of our approach to integrate ecosystem services in the German infrastructure legislation.

First, our approach to monetise the changes in the ecosystem service of habitat and gene pool protection assumes that the valued ecosystem services of the project and the study site of the contingent valuation are identical. To assess the area of an equivalent loss in ecosystem services we used the estimates from the environmental impact assessment[10]. However, the traditional German practice of conducting environmental impact assessment does not explicitly address ecosystem services, but so called ‘subjects of protection’[11]. The value we transferred to this loss was the willingness to pay of inhabitants of the same region for restoring natural floodplains by dyke relocation, extensifying agriculture and implementing species protection measures at the Elbe (Meyerhoff 2002). We approximate the loss of channel deepening with stated preferences for restoration measures which both are a composite of several ecosystem services, making it a relatively precise proxy. Nonetheless, we want to point out that this approximation has illustrative purposes and can neither replace a primary valuation nor should it be understood as a suggestion for a broad scale implementation of benefit transfers. A more precise approach would be to value all different ecosystem services changes by a project such as the Weser deepening separately. Such an approach to integrate ecosystem services hinges not only on the availability of bio-physical data, which can partly be gathered from the environmental impact assessment but also on

---

[10] Further contributions to this discourse are to be expected from the project Natural Capital Germany – TEEB DE (Naturkapital Deutschland - TEEB DE 2012).

[11] This encompasses the estimation, description and valuation of direct and indirect impacts on: (1) humans and human health, flora, fauna and biodiversity; (2) soil, water, air, climate and agriculture; (3) cultural goods; and (4) interdependencies according to the law on environmental impact assessment (German: “Gesetz über die Umweltverträglichkeitsprüfung”).

socio-economic information and societal preferences, which are not readily available. The resource intensity and difficulties to collect related socio-economic data resulted in the lack of representing environmental effects in the BVWP (Petry and Klauer 2005). Yet recent studies have gathered information on the value of ecosystem services from different water ecosystems (Russi et al. 2013) and, regionally more precise, Liekens, Broekx, and De Nocker (2013) identified values for single ecosystem services in estuaries around the North Sea region. Furthermore, there are attempts to integrate ecosystem services into strategic environmental assessments (Honrado et al. 2013; Karjalainen et al. 2013; Presnall et al. 2014) resulting in easier integration into CBA's.

Secondly, the well discussed limits to cost-benefit analysis (CBA) apply also to an ecological extended CBA (Hanley & Barbier 2009; Hansjürgens 2004; Pearce et al. 2006; Sen 2000). Case studies show the potential of public participation schemes along with economic valuation for river (Newson & Chalk 2007) and estuary (Fidélis & Carvalho 2014) management. Moreover, distributive effects are not explicitly considered in the welfare analysis according to the BVWP. Who benefits and who bears the cost is not stated. This applies especially, when ecosystem services are considered, which are often public goods and enjoyed by many, while benefits of developments are private and received by relatively small groups. A first step could be to make expected receptions of cost and benefits explicitly. In case of the Weser the channel deepening benefits shipping companies depending on large cargo transport, while for example either the state of Lower Saxony or the farmers of Wesermarsch will pay the price for the change in fresh water supply left the Weser. These could in a further step be accounted for in the CBA, for instance through well-known distributive weights (HM Treasury 2013).

Thirdly, uncertainty is neither systematically considered in the cost-benefit analysis nor in the environmental risk assessment (Petry and Klauer 2005). Long time horizons basically result in unavoidable uncertainty about the estimated cost and benefit streams. For instance, marginal abatement cost depends on technical innovation as well as on national and global stabilisation targets and mitigation path ways. An extrapolation far beyond 2050 is highly uncertain. Even though we reported uncertainty ranges for estimated figures, the uncertainty is not considered in the decision variable. This could be done for instance through an expected utility framework with a risk preference but would require to specify probability distributions (cf. Arrow & Lind 2014). Instead we here assumed a form of uncertainty in which states of the world are known and probabilities are unknown. A pragmatic approach to integrate uncertainty in the mild form of risk might be to employ probability distributions from expert interviews (Petry and Klauer 2005) with risk aversion factors from discursive processes as done in Switzerland (Umweltbundesamt 2012b).

5. Conclusion

In this paper we have analysed the decision making process in the German infrastructure legislation for the projected deepening of the Lower Weser and the integration of ecosystem services changes within it. We find that the Federal Transportation Infrastructure Plan ranks projects based on the economic feasibility measured by a benefit-cost ratio subject to public budget constraints. Effects on ecosystem services are not considered in monetary terms, except adding up a lump-sum figure for compensation measures on the investment cost. Excluding ecosystems services ignores effects of ecosystems on human wellbeing (Millenium Ecosystem Assessment 2005) and assumes that these can be completely substituted through compensation measures or that they have nil value. We furthermore find that a classification of costs as negative benefits systematically biases the benefit-cost ratio towards greater profitability. This shows that the decision to deepen the Lower Weser was based on an incomplete, biased, and therefore not reliable welfare assessment.

We reassessed the cost-benefit analysis of the Weser channel deepening and illustrated the relevance of these shortcomings in the German infrastructure legislation. We have shown that by integrating two major ecosystem services, namely the loss of ‘fresh water supply for agricultural production’ (left the Weser) and the loss in ‘habitat and gene pool protection services’ of the bio diverse estuary, the benefit-cost ratio drops substantially. We thus have given case study evidence, that ecosystem services are of relevant magnitude and integrating ecosystem services in the federal infrastructure planning process can substantially alter the results. This illustrates that if ranking of projects is mainly based upon monetary criteria than ecosystem service changes should be included in monetary terms in order to avoid an inefficient allocation of public spending. Furthermore, uncertainty in key benefit positions is very high but not reported, as exemplified for emission savings. All this calls for a substantial improvement of the standard methodology for infrastructure investment decisions with regard to bookkeeping and a standardized inclusion of affected ecosystem services.

On the bio-physical level a great part of the necessary information is already available in the mandatory environmental impact assessments and the related landscape conservation plan of ecosystem functions. Changes in ecosystem service can in principle be valued in monetary terms using existing methods (TEEB 2010b). However, to elaborate methods for a systematic integration of ecosystem services in the infrastructure legislation process based on existing information remains a domain for future research.

Acknowledgements

We are grateful to Stefan Baumgärtner, Moritz Drupp, Klaus Eisenack, Bernd Klauer, Martin Rode, Heinz Welsch, Martina Wernick, Ulrich Zabel and participants of the ISEE 2014 session T3 R4 1.3.O for helpful comments and suggestions on earlier drafts of this paper.

6. References

Arrow, K.J. & Lind, R.C., 2014. Uncertainty and the Evaluation of Public Investment Decisions. *Journal of Natural Resources Policy Research*, 6(1), pp.29–44.

BAW, 2004. *Fahrrinnenanpassung der Außenweser an die Entwicklungen im Schiffsverkehr sowie Tiefenanpassung der hafenbezogenen Wendestelle Summationswirkung der Anpassungen von Unter- und Außenweser Gutachten zur ausbaubedingten Änderung von Hydrodynamik und Salztran*, Hamburg: Bundesanstalt für Wasserbau.

BMVBW, 2003a. *Bundesverkehrswegeplan 2003*, Berlin: Bundesministeriums für Verkehr, Bau- und Wohnungswesen.

BMVBW, 2003b. *Die gesamtwirtschaftliche Bewertungsmethodik Bundesverkehrswegeplan -Bundesverkehrswegeplan 2003*, Berlin: Bundesministeriums für Verkehr, Bau- und Wohnungswesen.

Edenhofer, O. et al., 2014. Technical Summary. In O. Edenhofer et al., eds. *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press.

Ekardt, F. & Weyland, R., 2014. Neues vom wasserrechtlichen Verschlechterungsverbot und Verbesserungsgebot. *Natur und Recht*, 36(1), pp.12–20.

Fidélis, T. & Carvalho, T., 2014. Estuary planning and management: the case of Vouga Estuary (Ria de Aveiro), Portugal. *Journal of Environmental Planning and Management*, pp.1–23.

Franzius, L., Franzius, G. & Rudloff, R., 1894. *Seekanäle, Strommündungen und Seehäfen: Handbuch der Ingenieurwissenschaften* 2010th ed., Bremen: Salzwasserverlag.

GfL, BioConsult & KÜFOG, 2006a. *Fahrrinnenanpassung der Unter- und Außenweser an die Entwicklungen im Schiffsverkehr mit Tiefenanpassung der hafenbezogenen Wendestelle Umweltverträglichkeitsuntersuchung Auswirkungsprognose Überlagerungsvariante*, Bremen.

GfL, BioConsult & KÜFOG, 2006b. *Fahrrinnenanpassung der Unterweser an die Entwicklungen im Schiffsverkehr Landschaftspflegerischer Begleitplan*, Bremen.

Hanley, N. & Barbier, E.B., 2009. *Pricing Nature: Cost-benefit Analysis and Environmental Policy*, Cheltenham: Edward Elgar.

Hansjürgens, B., 2004. Economic valuation through cost-benefit analysis--possibilities and limitations. *Toxicology*, 205(3), pp.241–52.

HM Treasury, 2013. *The Green Book. Appraisal and Evaluation in Central Government*, London.

Honrado, J.P. et al., 2013. Can we infer about ecosystem services from EIA and SEA practice? A framework for analysis and examples from Portugal. *Environmental Impact Assessment Review*, 40, pp.14–24.

Horowitz, J.K. & McConnell, K.E., 2002. A Review of WTA/WTP Studies. *Journal of Environmental Economics and Management*, 44(3), pp.426–447.

IDN, 2008. *Fahrrinnenanpassung der Unter- und Außenweser an die Entwicklungen im Schiffsverkehr mit Tiefenanpassung der hafenbezogenen Wendestelle*, Oyten.

Intraplan, Planco & TUBS, 2014. *Grundsätzliche Überprüfung und Weiterentwicklung der Nutzen-Kosten-Analyse im Bewertungsverfahren der Bundesverkehrswegeplanung*, Essen, Berlin, München.

IPCC, 2014. Summary for Policymakers. In O. Edenhofer et al., eds. *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press.

IPCC, 2007. Summary for Policymakers. In B. Metz et al., eds. *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press.

ISL et al., 2000. *Entwicklungstendenzen der deutschen Nordseehäfen bis zum Jahre 2015*, Bremen.

Jochem, E. et al., 1997. Energieszenarien mit reduziertem CO2-Emissionen bis 2050. *Energiewirtschaftliche Tagesfragen*, 47(8), pp.474 – 481.

Johnston, S., 1981. Estuarine dredge and fill activities: a review of impacts. *Environmental Management*, 5(5), pp.427–440.

Karjalainen, T.P. et al., 2013. Integrating ecosystem services into environmental impact assessment: An analytic–deliberative approach. *Environmental Impact Assessment Review*, 40, pp.54–64.

Kuik, O., Brander, L. & Tol, R.S.J., 2009. Marginal abatement costs of greenhouse gas emissions: A meta-analysis. *Energy Policy*, 37(4), pp.1395–1403.

Liekens, I., Broekx, S. & De Nocker, L., 2013. *Manual for the valuation of ecosystem services in estuaries*, Available at: http://www.tide-toolbox.eu/pdf/reports/Manual_for_the_valuation_of_ES_in_estuaries_Final_report.pdf.

Luo, X.-L. et al., 2007. Effects of in-channel sand excavation on the hydrology of the Pearl River Delta, China. *Journal of Hydrology*, 343(3-4), pp.230–239.

Masuhr, K.P. et al., 1991. *Konsistenzprüfung einer denkbaren zukünftigen Wasserstoffwirtschaft*, Basel.

Meyerhoff, J., 2002. Der Nutzen aus einem verbesserten Schutz biologischer Vielfalt in den Elbauen: Ergebnisse einer Kontigenten Bewertungsstudie. In A. Dehnhardt & J. Meyerhoff, eds. *Nachhaltige Entwicklung der Stromlandschaft Elbe*. Kiel: Vauk, pp. 155–185.

Millenium Ecosystem Assessment, 2005. *Ecosystems and Human Well-being: Synthesis*, Washington, D.C.: Island Press.

National Research Council Marine Board, 1985. *Dredging Coastal Ports: An Assessment of the Issues*, National Academy Press.

Naturkapital Deutschland - TEEB DE, 2012. *Der Wert der Natur für Wirtschaft und Gesellschaft - Eine Einführung*, München, Leipzig, Bonn: ifuplan, Helmholtz-Zentrum für Umweltforschung - UFZ, Bundesamt für Naturschutz.

Newson, M. & Chalk, L., 2007. Environmental capital: an information core to public participation in strategic and operational decisions—the example of river “Best Practice” projects. *Journal of Environmental Planning and Management*, 47(6), pp.899–920.

Niedersächsischer Landtag, 2012. *Stenografischer Bericht 139. Sitzung am 21. Juni 2012*, Hannover: Niedersächsischer Landtag.

NLWKN, 2011. *Generalplan Wesermarsch Realisierungsstudie Gewässerregelung*, Norden.

Pearce, D., Atkinson, G. & Mourato, S., 2006. *Cost-Benefit Analysis and the Environment Recent Developments*, Paris: OECD Publishing.

Pearce, D. & Turner, R., 1989. *Economics of natural resources and the environment*, Baltimore: Johns Hopkins University Press.

Petry, D., Klauer, B. & with contributions from T. Döring and F. Rauschmayer, 2005. *Umweltbewertung und politische Praxis in der Bundesverkehrswegeplanung: eine Methodenkritik illustriert am Beispiel des geplanten Ausbaues der*, Marburg: Metropolis.

PLANCO, 2009. *Ergänzende Stellungnahme zu den Fahrrinnenanpassungen der Unter- und Außenweser an die Entwicklung im Schiffsverkehr - Analyse und Bewertung*, Essen.

PLANCO, 2002. *Gesamtwirtschaftliche Bewertung erwogener Wasserstrassenprojekte - Teilbericht Vertiefung der Unterweser*, Essen.

PLANCO, 2005. *Prognose der deutschlandweiten Verkehrsverflechtung - Seeverkehrsprognose*, Essen.

Presnall, C., López-Hoffman, L. & Miller, M.L., 2014. Adding ecosystem services to environmental impact analyses: More sequins on a "bloated Elvis" or rockin' idea? *Ecological Economics*, (in press).

Rundcrantz, K. & Skärbäck, E., 2003. Environmental compensation in planning: a review of five different countries with major emphasis on the German system. *European Environment*, 13, pp.204–226.

Russi, D. et al., 2013. *The Economics of Ecosystems and Biodiversity for Water and Wetlands*,

Schuchardt, B. et al., 2007. Vergleichende Bewertung der ökologischen Situation der inneren Ästuare von Eider, Elbe, Weser und Ems: Was hat sich nach 20 Jahren verändert. *Coastline reports*, 9, pp.15–26.

Sen, A., 2000. The discipline of cost-benefit analysis. *The Journal of Legal Studies*, 29(S2), pp.931–952.

Statistisches Bundesamt, 2014. Verbraucherpreisindex für Deutschland. Veränderungsraten zum Vorjahr in %. Available at: https://www.destatis.de/DE/ZahlenFakten/GesamtwirtschaftUmwelt/Preise/Verbraucherpreisindizes/Tabellen_/VerbraucherpreiseKategorien.html.

TEEB, 2010a. *The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A synthesis of the approach, conclusions and recommendations of TEEB.*,

TEEB, 2010b. *The Economics of Ecosystems and Biodiversity: The Ecological and Economic Foundations* P. Kumar, ed., London and Washington: Earthscan.

Umweltbundesamt, 2012a. *Best-Practice-Kostensätze für Luftschadstoffe, Verkehr, Strom- und Wärmeerzeugung. Anhang B der "Methodenkonvention 2.0 zur Schätzung von Umweltkosten,"* Dessau-Roßlau. Available at: http://www.umweltbundesamt.de/sites/default/files/medien/publikation/long/4485.pdf.

Umweltbundesamt, 2012b. *Methodenkonvention 2.0 zur Schätzung von Umweltkosten*, Dessau-Roßlau. Available at: http://www.umweltbundesamt.de/sites/default/files/medien/378/publikationen/uba_methodenkonvention_2.0_-_2012.pdf.

Wende, W., Herberg, A. & Herzberg, A., 2005. Mitigation banking and compensation pools: improving the effectiveness of impact mitigation regulation in project planning procedures. *Impact Assessment and Project Appraisal*, 23(2), pp.101–111.

Wetzel, V., 1988. *Der Ausbau des Weserfahrwassers von 1921 bis heute*, Berlin: Springer.

Wille, V., Preiss, P. & Friedrich, R., 2012. *Sachstandspapier zu Treibhausgase & Klimawandel, Sachstandspapier im Rahmen des Vorhabens "Schätzung Externer Umweltkosten und Vorschläge zur Kosteninternalisierung in ausgewählten Politikfeldern,"* Dessau-Roßlau.

WSV, 2011. *Planfeststellungsbeschluss für den Ausbau der Bundeswasserstraße Weser durch die Anpassung der Unterweser von Weser-km 8 bis Weser-km 65 und die Anpassung der Außenweser von Weser-km 65 bis Weser-km 130 an die Entwicklung im Schiffsverkehr*, Aurich.

Zabel, H.-U., 2011. Saaleausbau – wissenschaftliche Aspekte der Entscheidungsfindung. *UmweltWirtschaftsForum*, 19(1-2), pp.5–17.