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Public Policy Decision-Aiding

An instructive case study in simplified Multi-Criteria Decision Analysis as an impact assessment tool

by

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This thesis examines whether, and in what ways, simplified Multi-Criteria Decision Analysis (MCDA) can support ex-ante impact assessment in a public policy context. Using the Lynetteholmen construction project as an instrumental case, the study combines existing impact assessments, including environmental reports and cost–benefit analyses, into a unified assessment framework that evaluates Lynetteholmen against a base scenario.

The framework is applied in conjunction with a range of weighting schemes to explore the underlying priorities required for the project to be recommended over the base scenario. Sensitivity analysis is conducted through both manual variation of key inputs and Monte Carlo simulation.

The findings indicate that simplified MCDA has considerable potential as a means of integrating existing impact assessments, enhancing transparency, and clarifying the assumptions underpinning policy recommendations. These findings challenge the methodological predominance of Cost–Benefit Analysis as the default appraisal framework for public policy. Overall, the results suggest that embedding MCDA within established impact assessment practices could contribute to more rigorous, transparent, and well-founded decision-making in the public policy domain.

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AI Statement

As part of writing this Thesis, I have used Chat-GPT to assist me in writing R code used in the analysis. I have tested the code to ensure that there are no hallucinations messing with the results. In addition, I have used Chat-GPT to help translate accurately from Danish to English, and for synonyms. The rest of the words, and the thoughts, are mine.

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1. Introduction

1.1 A Massive Project

In October 2018, the Danish prime minister, flanked by the Lord Mayor of Copenhagen, held a press conference, announcing a plan to build a new island off the coast of Copenhagen. To the assembled journalists, and to the public at large, the plan was a complete surprise. As the prime minister put it, 30 seconds into the press conference:

> Today the government and the Municipality of Copenhagen have entered into a framework agreement on an extensive, long-term, and visionary harbor project.
>
> In brief: We will construct an island. A new island in the Øresund between Refshaleøen and Nordhavn (Statsministeriet, 2018).

The project, which would be one of the biggest urban development projects in Danish history, was described by the prime minister as a *kinder egg*, alluding to the multitude of challenges the project would be solving. Lynetteholmen, as the island was called, should provide housing for 35.000 people, streamline Copenhagen traffic, protect against Storm Surges, generate revenue to pay for new Metro lines, and dispose of excess contaminated soil from other construction projects (Statsministeriet, 2018). Construction was set to begin as soon as the necessary preliminary studies were conducted, to be completed in 2070. All in all, a massive undertaking.

Figure 1: The planned location of Lynetteholmen in Øresund (Rambøll, 2020, p.11).

In the aftermath of the announcement, reactions were mixed, with interest groups raising concerns about the environmental risks and questioning whether more conventional urban planning projects would be more suitable (Ritzau, 2021). Some resistance to the project has continued, with recent YouGov polling (commissioned by *Alliance to Pause Lynetteholmen*) showing that 60 % of respondents wish for the project to be reconsidered against other alternatives (YouGov, 2025). Despite the concerns, construction went ahead, with the first truckloads of soil deposited into the ocean in 2022.

1.2 And a Tiny One

Roughly 150 kilometers west of the spot on the ocean now set to become Copenhagen's new neighborhood in 2070, was the Langeskov Train Station, which had been reopened three years prior after a 40-year hiatus. One month after the Lynetteholmen press conference, the station was to be evaluated: Was it living up to the goals of reopening?

The evaluation was not favorable. Owing to overrun construction costs and incorrectly estimated user numbers, each 3-minute stop at Langeskov was overall costing travelers more than it was gaining (Buch-Larsen & Galbo-Jørgensen, 2018, p.9).

The bad evaluation meant the potential for Langeskov Station to be reduced from a regional to a local station, worrying locals, to whom the station had meant a renewed chance for their small community to withstand urbanization trends (Madsen, 2025).

1.3 A Simple Framework

Two different projects. One, a DKK 60 billion political prestige project; the other, a locally cherished but otherwise unimportant station, operating on a tiny budget. What do Lynetteholmen and Langeskov have in common? For both cases, the central evaluation tool that decides their fate is a Cost-Benefit Analysis (CBA).

In fact, across the range of public policy projects in Denmark, *Samfundsøkonomiske Analyser* (Societal-Economic Analyses, or CBA translated to Danish governance terminology) serve as critically important tools in ex-ante impact assessment, considering whether a given alternative is efficient (i.e., whether it will be more lucrative than costly to society if implemented). Often, they play a pivotal role in the final decisions made (Finansministeriet, 2023). For Lynetteholmen and for Langeskov, the result of the CBA, both of which were done with the same evaluation model (the traffic ministry's TERESA model), can be the difference between the project going ahead or being scrapped.

The CBA model reports, in monetary terms, whether the overall benefits outweigh the overall costs of a given project. It includes construction and operational costs, time spent by travelers, CO2 emissions, effects of public resource allocation, and so on – A complete picture of the economic and economy-adjacent impacts. What is not included, is the personal importance of Langeskov Station to the locals, the ability to see the ocean from the Copenhagen harbor, the possible impact on current flows in Øresund, or anything else that cannot reasonably be given a monetary valuation.

CBA's use in public policy evaluation has been criticized for reducing complex problems to overly simplistic solutions (O'Mahony, 2021, p.192), for being inaccurate and biased (Flyvbjerg & Bester, 2021), and for the neoclassical economic assumptions that underpin it, challenging its status as an objective method (Atkinson et al., 2018, p.38).

Because of this, many researchers have argued the need for an expansion of decision-aiding tools in public policy to better capture non-monetary aspects, and which better allow for political visions to guide decision-making.

1.4 And a Complicated One

One such tool, Multi-Criteria Decision Analysis (MCDA), has received increased attention in recent years (Dean, 2020, p.167). MCDA aims to combine disparate impacts which cannot be monetized and are not directly comparable with stakeholder and decision-maker preferences or visions in a single framework (Munda, 2004a, p.665). The method rejects objectivity, instead aiming to include subjective judgements directly in the process. When successful, MCDA should give decision-makers recommendations regarding the efficacy of available possibilities, accompanied by clarity and transparency regarding *how* the analyst arrived at these conclusions.

This is no small task, and MCDA practitioners have met considerable resistance to broader implementation. While the method has a longstanding tradition in health-care and environmental policy evaluation, it is often considered a costly and cumbersome addition to CBA in public policy contexts (Cinelli et al., 2020, p.2; Dean, 2020, p.167). As such, it is used only in cases with exceptionally high complexity, if at all. In Denmark, at the federal level, it seems to be completely unrecognized.

1.5 A Useful Alternative

The dominance of CBA as the pivotal impact assessment tool in public policy processes risks biasing decision-making towards the assumptions which it relies on. This could potentially be remedied through the addition of a more open-ended decision-aiding framework. However, as long as MCDA is (rightfully) viewed as an overly complex alternative, it is unlikely to be adopted as an impact assessment tool. What can be done to make MCDA a more attractive and useful alternative?

1.5.1 Research Question

In this thesis, I examine MCDA through a practical example, seeking to uncover whether a simplified version of MCDA retains its strengths and thus becomes a viable addition or alternative to CBA. In constructing my MCDA framework, I attempt to tailor it to integrate easily with existing Danish planning processes, simplifying and streamlining as much as possible without hollowing out the approach. I ask the question:

> *How can a simplified Multi-Criteria Decision Analysis be used to support ex-ante impact assessment within public policy processes?*

I approach this question through an instrumental case study of Lynetteholmen with a primary focus on methodological MCDA considerations and sensitivity analysis, considering:

- *Under which conditions does the simplified MCDA favor enacting the Lynetteholmen plan over not doing so?*
- *How sensitive are these conclusions to changes in scores and criteria weights?*

In section 2, I examine the history of CBA and its critiques more thoroughly and look into MCDA in public policymaking as an alternative. Section 3 contains a thorough accounting of the data I use and of my methodological choices and considerations. I carry out my analysis of the Lynetteholmen case in section 4. In section 5, I discuss my results, their validity and the broader implications. Finally, I draw conclusions in section 6.

2. History and Critique – State of the Art

In this section, I give a historical overview of the use of Cost-Benefit Analysis (CBA) as an impact assessment tool in public policy evaluations, and an outline of the core tenets of CBA today. I then delve into the critiques of CBA and how proponents and detractors have attempted to alleviate CBA weaknesses.

Based on the CBA critiques, I propose Multi-Criteria Decision Analysis (MCDA) as an alternative or addition for impact assessment in complex cases, where the weaknesses of CBA render it inadequate. I then outline the state of the art in the MCDA literature and how this thesis can add to it.

2.1 The history of CBA in public policy

In the period following the great depression, the United States significantly expanded its public sector under the *New Deal* policy regime. This expansion of governmental activities gave rise to discussions about the efficacy of public initiatives and how to ensure their efficiency (Hufschmidt, 2011, p.40). A multitude of new policy evaluation instruments were introduced to ensure rational planning, among which CBA (originally benefit-cost analysis) was put forward as an expansion of profit-and-loss models (Jiang & Marggraf, 2021, p.7). Whereas profit-and-loss accounting only included the monetary gains compared to the price of a given project, CBA added *social welfare* and *externalities*, attempting to give a more complete picture of the societal costs and benefits (Quah & Toh, 2012, p.6).

Social Welfare

Social welfare (Dupuit 1844 & Marshall 1890) is synonymous in CBA with consumer surplus, and defines the total social welfare as the cumulation of each individual's welfare. This utilitarian and individualistic understanding of welfare underpins CBA and economic policy evaluation thinking to this day (Mouter et al., 2020, p.228; Quah & Toh, 2012, p.6).

CBA formalizes social welfare through the Kaldor-Hicks compensation criterion, which considers "[s]ocial state A *socially preferable* to an existing social state B if those who gain from the move to A can compensate those who lose and still have some gains left over." (Munda, 2017, p.4).

In theory, the Kaldor-Hicks criterion mimics a Pareto improvement (which requires someone to be better off and no one to be worse off), but only in the case that compensation actually is made, which is rarely the case (Ekardt, 2022, pp.112–113).

Externalities

Externalities (Pigou 1920), is a core concept of the economics discipline, denoting any effect not directly factored into a decision or transaction by the relevant actors (Quah & Toh, 2012, p.6).

A typical example is the pollution emitted by one car model vs. another, which will be external to the pricing since neither buyer nor seller of the car will bear the environmental burden of increased pollution.

If all externalities are included in the model, a CBA should give a complete picture of the benefits and costs to social welfare of a given decision, enabling policymakers to choose the most efficient solution (Mishan & Quah, 2007, p.90).

Box 1: Social Welfare and Externalities. Based on Quah & Toh, (2012), p.6.

The first directive to mandate the use of CBAs (or CBA-like analyses) was the US Flood Control Act of 1936, which mandated the use of cost and benefit impact assessment for any new initiatives regarding flood control (Hufschmidt, 2011, p.42; Jiang & Marggraf, 2021, p.7).

Following the 1936 act, the institutional use of CBA proliferated, with US planning agencies gradually institutionalizing cost-benefit style analyses. At this point, however, there existed no clear or unified guidelines for how to carry out accounting and evaluation as part of welfare impact assessments (Quah & Toh, 2012, p.7). As such, many of the agencies' impact assessments would contrast one another, having been based on different methods (Hufschmidt, 2011, p.42).

Concurrently with the proliferation within the US federal government, welfare impact assessments had garnered attention in the field of economics, with a series of neoclassical economists expanding on the approach and combining it with economic methods of accounting and modeling, establishing during the 1940s the first ideas of CBA as it is used today (Hufschmidt, 2011, p.44; Mishan & Quah, 2007, p.243).

In 1950 and 1952, two documents (the so-called Green Book report and Budget Circular A-47) were released, which aimed to consolidate and streamline the use of welfare impact assessments across agencies (Hufschmidt, 2011, p.43; Jiang & Marggraf, 2021, p.8). The release of the Green Book and A-47 further intensified interest within the economics field, prompting many economists to focus on welfare accounting and valuation methods (Mishan & Quah, 2007, p.244).

From there, CBA gradually took a central role in both the economics discipline and public policy (Hufschmidt, 2011, p.44). By the mid-1960's, CBAs were required as part of any large-scale government projects in the US, Canada and the UK. By the start of the 1970's, the OECD, UN, and the World Bank were on board as well (Mishan & Quah, 2007, p.244). The prominent role of economics in public policymaking today is closely linked to the rise of CBA, grounded in research from the 1950s and early 1960s (Quah & Toh, 2012, p.8). It is predominately through their use of CBA that economists aid and influence political decision-making.

2.2 Modern CBA

Over time, choices regarding inclusions and exclusions of different aspects, methods of accounting and monetization, and methods for modeling, have gradually been optimized and transformed, with more externalities included, utilizing more exact economic valuation techniques and complex mathematical accounting formulas (Atkinson et al., 2018, p.44; Atkinson & Mourato, 2008, p.318; Jiang & Marggraf, 2021, p.9). Even so, the overall steps of CBA remain largely unchanged. Box 2 provides an overview of the CBA process.

Cost-Benefit Analysis in four Steps

Step 1 – Framing the decision and setting boundaries

Analysts define the boundaries of the problem, the alternative solutions, and the *base scenario* which alternatives are judged against. Analysts also determine which people and areas are relevant when determining consumer (social) surplus.

Step 2 – Valuation and Monetization

All impacts are quantified into a single monetary unit.

Step 3 – Discounting and Aggregation

The Social Discount Rate is applied to the impacts, yielding a Present Value for each impact.

All discounted costs and benefits are aggregated to reveal the Net Present Value, representing the total impact of the policy option and allowing comparison to other options and the base scenario.

Step 4 – Final Assessment and Robustness Testing

A project is sanctioned if the sum of benefits exceeds costs, meaning the Net Present Value is positive: PV(B)-PV(C)>0. Other assessment instruments include the Benefit-Cost Ratio: PV(B)/PV(C).

CBA practitioners will usually employ sensitivity analysis of key input parameters (such as discount rate or certain cost estimates) to map and alleviate the bias introduced by uncertain estimates.

Box 2: Step-by-step CBA. Based on Atkinson et al. (2018), pp.33–36; Munda (2017), p.7 and Saarikoski et al. (2016), p.239.

Both practitioners and critics agree that valuation and monetization is the most complicated and contestable step (Beria et al., 2012, p.147). In order to transform non-market goods and services into monetary units, practitioners use a series of techniques, all of which are rooted in attempting to assess what the market value would have been, if the goods had been on the market (Atkinson et al., 2018, p.35).

The most common valuation techniques fall under either Revealed Preference (inferring value through observable behavior in markets), Stated Preference (eliciting hypothetical preferences through surveys and experiments), or Value Transfers (applying monetary values derived in previous studies to a new context) (Atkinson et al., 2018, pp.55–78). Value Transfer databases are continually expanded, allowing practitioners to avoid the arduous and costly processes of valuating all impacts from scratch. As Value Transfer databases expand, the cost and time requirement of CBAs is lowered, making it an increasingly attractive method (Atkinson & Mourato, 2008, pp.326–328).

Market-priced impacts are often adjusted to account for distortions such as taxation and unemployment, a practice known as Shadow Pricing (Atkinson & Mourato, 2008, p.318).

Revealed Preference Approaches

Travel Cost

Measuring how much time and money people are willing to spend to enjoy non-market goods, e.g. travel to recreational sites.

Hedonic Pricing

Breaking down composite assets into their component parts to reveal the willingness to pay for non-market components, e.g. subtracting all market-based aspects from housing prices to reveal real valuation of air pollution.

Averting Behavior

Examining the costs incurred by people attempting to insulate themselves from a non-market bad to reveal its value, e.g. staying indoors or installing an air-filter to avoid air pollution.

Box 3: Preferences Approaches. Based on (Atkinson et al., 2018, pp.55–78).

Because individuals usually prefer benefits sooner rather than later, costs and benefits that occur in the future are discounted, using a Social Discount Rate, yielding a Present Value for each impact. While there have been many studies attempting to accurately assess the appropriate discount rate, the rate is largely a convention, reflecting judgment rather than a precisely determinable value (Atkinson & Mourato, 2008, p.330).

2.3 Critique of CBA

CBA was developed to provide a more rigorous, objective, and societally focused instrument for evaluation of policy proposals. It has been incredibly successful. Most major policy proposals in western countries and international organizations are today subject to CBA, the results of which is often the key inflection point for whether a proposal is accepted or not (Atkinson et al., 2018, p.20; Beria et al., 2012, p.139). Along the way, however, numerous critiques of the method have arisen, pointing to blind spots and biases which are not easily remedied (Beria et al., 2012, p.140).

In the context of an increased focus on environmental degradation and climate change – non-market impacts which CBA struggles to quantify satisfactorily – the literature criticizing CBA has proliferated. Some major critiques include CBAs handling of distribution, sustainability, and transparency.

2.3.1 Distribution

A considerable shortcoming of traditional CBA is its insensitivity to distributional concerns. An acceptable/successful project, as defined under the Kaldor-Hicks criterion, is one which is *efficient*, meaning the overall resources used are lower than the overall resources gained (Adler, 2013, pp.1–2). This measurement is entirely indifferent to the question of *whom* benefits accrue to, so long as benefits outweigh the costs. Proponents of CBA argue that if public projects are efficient, that will ensure that net gains are maximized, after which distribution can be handled separately through taxation or other political instruments (Adler, 2013, p.27; Atkinson & Mourato, 2008, p.328).

Unsatisfied with this solution, some researchers have argued in favor of weighted CBA, which weights each impact depending on the people who will likely be impacted (Adler, 2013, p.2). Weighted CBA utilizes the Social Welfare Function, a systematic framework for operationalizing a given social objective. The Social Welfare Function replaces the Kaldor-Hicks criterion, bringing interpersonally comparative utility into the heart of analysis (Fleurbaey & Abi-Rafeh, 2016, p.286).

In practice, most weighted CBA approaches are underpinned by the simple principle that money has greater value for the poor than for the rich (Fleurbaey & Abi-Rafeh, 2016, p.286). Proponents of weighted CBA argue that this disparity should be factored in by weighting impacts on poorer people higher and impacts on richer people lower. Rather than distributional issues being considered separately, they should be included in the early analytical steps, yielding a result in which benefits outweighing costs also means that the evaluated policy is distributionally sound (Adler, 2013, p.1; Atkinson et al., 2018, p.275).

While weighted CBA solves issues of the distributional indifference of traditional CBA, it too has its drawbacks. Firstly, specifying a given Social Welfare Function is at base a normative decision, which leaves it vulnerable to bias and criticism (Adler, 2013, p.23; Fleurbaey & Abi-Rafeh, 2016, p.296). Secondly, the resulting analysis is usually highly sensitive to changes in distributional weights, which can undermine the validity of its conclusions (Atkinson & Mourato, 2008, p.329).

2.3.2 Sustainability

An easily overlooked assumption in CBA is the substitutability of different forms of benefits – In the act of monetization exists also an act of equalization (Beria et al., 2012, p.139). Any monetary amount is equivalent to another monetary amount, regardless of whether the original impact was time spent in traffic or nitrogen in the groundwater (Tiwari, 2000, p.260). This equalization, even if the monetization is accurate to some *true value* of the monetized impacts, leads to issues, when some impacts are irreversible and thus not substitutable with others (Dietz & Neumayer, 2007, p.619). Removing the habitat of certain species cannot later be made up for with the funds gained from the building project.

This issue is discussed by some critics as a question of weak versus strong sustainability. Traditional CBA aligns with a weak sustainability understanding, recognizing environmental impacts and concerns as worth including in the model, but giving it no special emphasis as compared to other aspects (O'Mahony, 2021, p.181). Strong sustainability proponents, on the other hand, argue that environmental impacts by their irreversible and non-substitutable nature need to be handled separately from other aspects (O'Mahony, 2021, p.193). They argue that a certain level of Critical Natural Capital must be preserved regardless of the tradeoffs, and that any impact assessment framework needs to account for this (Dietz & Neumayer, 2007, p.618).

Proponents of a strong sustainability framework have argued in favor of the inclusion of certain thresholds, which the solution alternatives must not exceed. As such, the strong sustainability position is not so much an addition to CBA as it is a foundational change to the parameters (Atkinson et al., 2018, p.287). CBA can be carried out *as normal* but must fit within pre-established boundaries (Dietz & Neumayer, 2007, p.622). This approach may be suitable to avoid crossing environmental boundaries, but it weakens the arguments favoring CBA. If one of the strengths of CBA is the ability to compare impacts, giving one impact preferential status undercuts the usefulness. Furthermore, this approach gives us little assistance in terms of how to assess what the Critical Natural Capital levels should be.

Outside of the weak vs. strong sustainability debate, milder critiques of CBAs handling of environmental concerns have also been levied. These critiques center on the importance of discounting rate, since many environmental impacts play out over decades or centuries, which lowers their weight in the analysis when future costs and benefits are discounted (Atkinson & Mourato, 2008, p.330). A typical discount rate of 4% pr. year (Mouter et al., 2020a, p.244) results in an impact calculated 50 years from now receiving a weight of ≈ 0.17, meaning it's weighted as approximately 17 % of an impact happening this year. An impact calculated in 100 years would be weighted at ≈ 0.02, or 2 %.

Critics have argued that this weighting undervalues the importance of environmental impacts happening over the long term, which has resulted in the adoption of a gradually declining discount rate (Atkinson & Mourato, 2008, p.331). The Danish Traffic Ministry now uses 4 % until 35 years, then 3 % until 70 years, and finally 2 % (Transportministeriet, 2015, p.97). The difference means that an impact calculated 50 years from now will instead be weighted at ≈ 21 %, and an impact calculated in 100 years would be weighted at ≈ 8 %. This example shows how CBA practitioners are trying to adapt the method to account for modern challenges. It also shows the extent to which normative and methodological choices can change the result of the analysis, challenging its self-purported status as objective.

2.3.3 Transparency

As we've seen, the results of CBA are heavily influenced by choices regarding valuation and discount rate. However, the output of the CBA, the Net Present Value figure, gives no such indication. This leads to what I call the *Engine Room* problem.

When used as an impact assessment tool, CBA is supposed to strengthen decisionmakers' ability to make choices. Those political choices should consider efficiency, but are also based on goals, values, preferences, and normative questions (Ekardt, 2022, pp.1–2). However, with conclusions so reliant on decisions being made by analysts during the analytical process (in the *Engine Room*), decision-makers are often presented with a foregone conclusion which requires strong opposition to overcome (O'Mahony, 2021, p.192)

Proponents of CBA argue that their methods of valuation provide the most accurate estimates for the real value of impacts, based on the actual preferences of consumers (Mishan & Quah, 2007, p.240; Saarikoski et al., 2016, p.239). Detractors argue a) that *most accurate* is still often severely inaccurate, with many environmental scientists disagreeing with current estimates used in CBA (Ekardt, 2022, pp.77–84); b) that consumer preferences are not necessarily the best metric for complex impacts (Saarikoski et al., 2016, p.244); and c) that some policy-makers may (and often will) have specific issues that they value higher, which is not included in the CBA (Atkinson & Mourato, 2008, p.335).

The *Engine Room* critique can be boiled down to this: CBA ceases to be useful as an impact assessment tool if the goals of decision-makers are not aligned with both the definition of welfare inherent in the Kaldor-Hicks criterion, the valuation and prioritization of each impact, and the discount rate chosen. When any of these aspects of analysis are unaligned with decision-maker priorities, CBA risks becoming a coercive force rather than a useful tool. Despite continual improvements of the methodology, this point remains irreconcilable.

2.4 CBA as decision-making aid

The shortcomings of CBA are not easily overcome. Although numerous attempts have been made at reforming and adding to the approach, only few are implemented at large, and many issues continue to be unsolved. However, the attempts at reformation generally arrive at the same issue: Who will make the normative decisions regarding the importance of distribution, environmental impacts, future discount rate, success criteria etc.?

CBA emerged in the first half of the 20th century, attempting to provide a rigorous framework for evaluating social welfare without bias and normativity. But the normative questions persisted and accumulated. With the increased importance of these normative questions, CBA seems poorly equipped to handle impact assessments of the future.

2.5 Multi-Criteria Decision Analysis

While CBA was becoming influential in planning, economics, and policy, Multi-Criteria Decision Analysis (MCDA) emerged as a contrasting approach to structuring complex decisions, which rejects commensurability of evaluated impacts (Beria et al., 2012, p.138; Dean, 2020, p.167). In MCDA, the measurements used for each impact are field-specific, without an attempt to quantify or valuate. Instead, the result of an MCDA is a recommended solution, coupled with a hierarchical ranking of the contribution of each impact to the recommendation, allowing decision-makers to consider whether the ranking and the recommendation is consistent with their goals (Mouter et al., 2020a, p.227).

To overcome the problem of hidden normativity, Multi-Criteria Decision Analysis (MCDA) highlights differing values and tradeoffs, making normative judgements explicit and central to the analysis (Munda, 2017, p.14). The steps of an MCDA are outlined in Box 4.

Multi-Criteria Decision Analysis in Five Steps

Step 1 – Problem Identification and Structuring

First, the problem which requires a decision is identified and defined. As part of this step, relevant stakeholders (policy-makers, experts, special-interest groups, interested and affected parties) are identified.

Step 2 – Defining Alternatives and Criteria

Potential solutions, actions, and projects are listed. These alternatives are those which the MCDA process aims to choose between.

Then, the criteria upon which the alternatives will be evaluated are identified. Criteria can be qualitative or quantitative, and can range across financial, social, environmental or any other fields.

Step 3 – Scoring (Performance Measurement)

Each alternative is measured on each criteria. The measurements need to be consistent across alternatives (if *cost* is chosen as a criteria, each alternative must have a *cost* assigned to them), but can vary across criteria (*cost* can be measured in monetary units, while CO_2 can be measured in kg).

Step 4 – Weighting (Preference Elicitation)

Stakeholders or decision-makers are asked to rank and weight criteria by their (relative) importance.

Step 5 – Model Application, Sensitivity Testing, and Synthesis

The inputs (criteria weights and alternative scoring) are used in an MCDA model to produce a recommendation about the best alternative or a ranked list of the alternatives.

Important inputs, like outlier scores or weights, are varied to test the robustness of the recommendation.

Box 4: Step-by-step MCDA. Based on (Munda, 2017, p.12; Saarikoski et al., 2016, p.240).

Contrasting MCDA with CBA, three main differences emerge: First, MCDA compares impacts without standardizing the measurement unit, keeping the impacts separated (Beria et al., 2012, p.138). Second, MCDA allows for (and requires) normative specification of the weight put on each impact relative to each other (Mouter et al., 2020a, p.232). Third, MCDA delivers a recommendation which is more transparent, but also more complicated to interpret (Mouter et al., 2020a, p.234). In MCDA, the most contentious steps are 1 (choosing stakeholders) and 4 (eliciting preferences and weighting schemes).

2.5.1 Participatory or Analyst-led

One of the main discussions in the MCDA literature is whether and to what extent the analytical process should be participatory. In analyst-led MCDA – the approach most similar to a CBA process – the scoring and weightings will be based on surveys with field-specific experts. This has caused some criticism of MCDA as an *expert-led* approach (Mouter et al., 2020a, p.228).

According to this critique, the consumer preference which governs CBA has simply been replaced by expert preference.

To remedy this, many MCDA proponents have explored the idea of Participatory MCDA, which invites stakeholders at multiple levels to participate in the analysis, predominately in step 1, 2, and 4. By inviting stakeholders, here-in decisionmakers, experts, special-interest groups, and other interested and affected parties, the aim of objectivity is replaced with the aim of consensus (Dean, 2020, pp.204; 208; Munda, 2004b, p.671). This approach attempts to increase democracy, transparency, and justice, by opening the *Engine Room* and including discussion from the start.

While the principle is sound, there are still some potential issues. Firstly, the choice of which stakeholders to include is important yet ambiguous and can easily become part of a political ploy to capture the decision-making process (Dean, 2020, p.208; Mouter et al., 2020a, p.231). Secondly, in the first step, Problem Identification, participatory processes can be laden with power struggles as actors attempt to define the problem as they see fit (Dean, 2020, p.214; Munda, 2004b, p.673). The process may be democratic, but it is not necessarily cooperative, and it can be difficult for disadvantaged stakeholders to keep up. Finally, since participatory processes are generally slow, cumbersome and costly, participatory MCDA is very much an ideal, with far more attention paid to it in the academic literature than examples in actual decision-making processes (Dean, 2020, p.215). In practice, many MCDA processes employ a mix of participatory and analyst-led approaches, with stakeholders invited to participate in some parts of the process but not in others, and often not at all.

2.5.2 A multitude of options

Beyond the participation/analyst-led distinction, the moniker MCDA actually contains a multitude of different methodological branches, differing on elicitation methods, hierarchical/non-hierarchical organizations of impacts, how weights and scores are combined, and how to report the results and give a recommendation (Cinelli et al., 2020; Dean, 2020, p.172). Box 5 contains an outline of the main schools of thought.

Multi-Criteria Decision Analysis Schools

Full Aggregation Methods

Full aggregation models regard each impact/criterion as compensatory, similar to MCDA.

They result in a fully aggregated score, which typically recommends one alternative over the others.

Value Function Models transform performance metrics onto a common scale, assigns scores and weights to the metrics, then aggregates them.

Model Names: MAVT; MAUT; SMART; SMARTER

Hierarchical Models decomposes the performance metrics into overall goals, underlying criteria, and indicators. Pairwise comparisons are performed within each category to derive ratio-scale priorities.

AHP; Best-Worst Model

Outranking Methods

Outranking Models regard impacts as non-compensatory, and focus on pairwise comparisons to establish preferences or degree of dominance.

They result in rankings of alternatives which show alternatives which are dominated and alternatives which mutually outperform each other on different criteria.

Model Names: ELECTRE; PROMETHEE

Reference Point Methods

Aims to find a satisficing solution by minimizing the deviation from desired aspiration levels (goals) or reference points.

Used primarily when the feasible set of alternatives is large or infinite.

Box 5: Overview of main MCDA approaches. Based on Cinelli et al., (2020) and Dean (2020).

Proponents of the more elaborate models argue that they are more accurate and appropriate for the high-complexity situations in which they aim to assist (Danielson, 2009, p.1; Munda, 2017, p.8). The issue, however, is that these models are mathematically dense and practically complex to implement, requiring a high degree of specialized knowledge from the analyst, along with a large time- and energy investment from participants (whether that means full stakeholder participation or just experts) (Barfod & Leleur, 2014, p.22; Dean, 2020, p.214). In addition, interpreting the results of the more complex MCDA frameworks requires a higher level of understanding of the methodology, rendering it less useful as a decision-aiding tool for politicians and non-experts (Cinelli et al., 2020, p.10; Danielson, 2009, p.4). It is a reasonable assertion that commensurability in impacts is unrealistic, but it is also reasonable to develop a model which practitioners and decision-makers are actually capable of using.

There is a wealth of literature exploring increasing model specificity and accuracy, but far fewer examples of MCDA being used in practical decision-making processes (Dean, 2020, p.214). When it is used, as in Britain, where MCDA has made inroads in construction planning beginning in the 1990's, it is generally a simplified framework which is put in use (Danielson, 2009, p.6). Furthermore, meta-analyses of the use of MCDA show that non-experts find the methods challenging to comprehend, complicating the process of putting the more complex MCDA-approaches into practice (Digkoglou et al., 2024, p.21). Given these circumstances, more effort should be devoted to exploring the potential of simplified and practice-oriented MCDA and providing non-expert public analysts with options to implement such analyses in their work.

2.6 Bridging Theory and Practice

My aim, then, is to contribute to the literature by way of an example. I will conduct a simplified and pared-down version of an MCDA-analysis, which is directly integrated with and based on existing impact assessments which are already legally required in Danish planning processes, and which compares only one solution alternative to a base scenario (as is done in CBA). With this approach, I wish to explore whether a substantially simplified MCDA-approach can still prove a useful decision-making aid, and thus whether there is a practical opportunity to add MCDA to the toolkit of the civil service.

3. Methodology

Since the Lynetteholmen project has already been approved and is underway, there is not much use in comparing different alternative solutions, as would be the approach in a typical ex-ante MCDA analysis. Since we know that the choice was made to enact the Lynetteholmen project in its current form rather than choosing a different solution, we also know that the political prioritization of different aspects and impacts resulted in the project being assessed as a viable and good solution – certainly better than no intervention at all.

Utilizing this fact – Lynetteholmen was considered better than no intervention – I use simplified MCDA techniques to open up the engine room, seeking to clarify what prioritizations, rationales, and implicit judgements, underlie the resulting decision.

To do this, I compare Lynetteholmen to a base scenario using simplified MCDA. A base scenario is one in which no intervention is enacted, meaning that all costs and all benefits are set to 0. Comparing alternatives to a base scenario is the typical practice in CBA and in other impact assessment approaches used in planning practice, so utilizing a base scenario for simplified MCDA creates comparability across frameworks.

I ask two questions:

- *Under which conditions does the simplified MCDA favor enacting the Lynetteholmen plan over not doing so?*
- *How sensitive are these conclusions to changes in scores and criteria weights?*

To answer these questions, it is necessary to a) decide on the relevant metrics to evaluate the alternatives – *Criteria*; b) measure each alternative's performance on those criteria – *Scores*; c) add the relative priority of each criterion – *Weights*; and d) ascertain the confidence in the results – *Sensitivity*.

First, an overview of existing impact assessment documents which make up my empirical foundation.

3.1. Data

Before construction began on Lynetteholmen, the project underwent a series of impact assessments. These assessments are legally required for largescale construction projects in Denmark (in accordance with the Danish Planning Act and EU-directives), and include an

Environmental Impact Assessment (EIA), a Strategic Environmental Assessment (SEA), and finally a Societal-Economic Analysis (CBA) (Miljø- og Ligestillingsministeriet, 2023) (Box 6).

Impact Assessment Reports

Environmental Impact Assessment

LYNETTEHOLM
MILJØKONSEKVENSRAPPORT

24 Impacts Categories	684 Pages	3 Significantly Negative Impacts	24 Moderately Negative Impacts

Strategic Environmental Assessment

PLAN FOR BYUDVIKLING OG INFRASTRUKTUR TIL ØSTHAVNEN, HERUNDER LYNETTEHOLM

9 Impact Categories	281 Pages (5 appendixes)	37 Significantly Negative Impacts	45 Moderately Negative Impacts

Cost-Benefit Analysis

SAMFUNDSØKONOMISKE EFFEKTER VED UDVIKLING AF ØSTHAVNEN

8 Impacts Calculated	76 Pages (5 appendixes)	Costs: DKK 35.1 billion	Benefits: DKK 50.1 billion

Box 6: The three Lynetteholmen impact assessment reports and their results.

The reports are detailed and comprehensive accountings of the estimated effects of construction and operation on the surrounding environment, population, and economy. They include categories ranging from CO2 emissions and marine wildlife to cultural heritage sites, sailing conditions, and traffic. The reports ensure that the project is sound and doesn't break any laws or regulations. In addition, the reports are the basis for public hearings, and for the final decision-making process regarding the project.

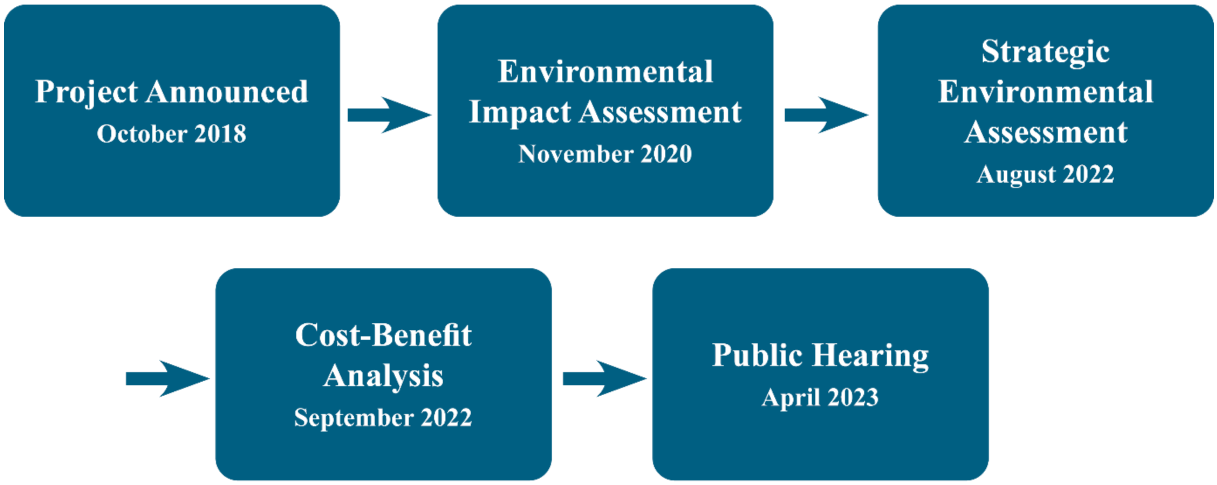

Figure 2: Timeline of documents and public processes for Lynetteholmen.

In total, the EIA found 27 impacts to be significantly or moderately negative (Rambøll, 2020, pp.663–667), while the SEA found 85 impacts to be significantly or moderately negative (Transportministeriet, 2022a). The CBA concludes that the project has a Present Net Value of DKK 14.5 billion, meaning the total benefits outweigh the total costs over the period by this amount.

These reports are comprehensive, complicated and field-specific tomes, whose results and conclusions are difficult to decipher for non-experts. There is no clear indicator whether 25 impacts are many or few, and neither the EIA nor the SEA offers clear conclusions on the overall efficacy of the Lynetteholmen project. Furthermore, it is unclear to what extent the EIA's and SEA's findings (or the public hearing) influenced decision-making in the case of Lynetteholmen.

Except for securing the legality of the project, it is difficult to justify the combined nearly 1000-page reports. In the remainder of this section, I combine the impacts assessed in the EIA, SEA, and CBA into a simplified MCDA framework. By utilizing the data and assessments contained in these existing reports, I minimize the complexity and expenses of conducting an MCDA.

I am testing MCDA in a supportive capacity, not as a full-scale alternative model. Therefore, the data used in this thesis is secondary, relying entirely on the EIA, SEA, and CBAs data.

3.2 Criteria

The EIA, SEA, and CBA each use different scales to evaluate the impacts they cover, as seen in Box 7.

Document Evaluations

EIA	–	The EIA reports only negative impacts, with four possible evaluations:		
		None/Insignificant	Small	
		Moderate	Significant	
SEA	–	The SEA reports negative and positive impacts with six possible evaluations:		
		Significant Negative	Moderate Negative	None/Insignificant
		Moderate Positive	Significant Positive	*Too early to tell*
CBA	–	The CBA calculates 8 impacts in DKK.		

Box 7: The different evaluation schemes for the three impact assessment documents.

To create a useable scoring regime, these disparate evaluations must be unified into a comparable metric. Furthermore, with upwards of 100 impacts in total, the number must be drastically reduced to simplify analysis. While there is no settled best practice for the number of criteria to include in MCDA, the typical recommendation lies somewhere between 6 and 20 (Dean, 2020, p.200).

To reduce the number of impacts, I have first removed all impacts from the EIA and SEA which were evaluated as none/insignificant, since these would not differ from the base scenario.

Then, I have combined impacts within each document which are similar to one another, averaging evaluation across. For instance, in the SEA (which evaluates each construction stage of the Lynetteholmen project separately), some stages of the Lynetteholmen project were evaluated to have significant negative impacts on Benthic Fauna, while other stages were evaluated as having no impact (Transportministeriet, 2022b, p.7 [Appendix 5]). I have averaged this as Benthic Fauna: Moderate Negative Impact, while recording the range. This reduced the number of impacts to 46.

With impacts aggregated to the extent possible, I labeled (coded) each impact into a category, based on the in-depth descriptions contained in the documents. This first coding was inductive, meaning I had no set criteria that I was aiming for, but added a new criterion whenever an impact did not fit well within those criteria already added. The inductive coding resulted in 8 categories: Conservation, Economic Effects, Environmental Effects, Health & Wellbeing, Housing, Recreation, Resource Use, Traffic. The full list of impacts and their codes are found in “Appendix 1 – Impacts and Criteria Coding”.

To avoid double counting, I combined impacts which were present in more than one of the impact assessment documents, and which were assessed similarly between them (Belton & Stewart, 2002, p.56). For instance, the impact Appearance in the SEA is duplicated in the EIA as Landscape and are assessed as being a small-moderate negative impact in both documents. In those cases where the impacts were assessed differently across documents, both impacts were retained (for instance, the CBA evaluates External Effects (air and noise pollution) as a small positive impact, whereas the SEA and EIA both evaluate Air Quality and Noise as small or moderate negative impacts. Since the evaluation of these impacts is directly opposed, the retention of multiple identical impacts here should not be considered double counting. As these impacts will be combined into a single score for a criterion, retaining them at this stage adds transparency, while being mathematically similar to collapsing the impact and averaging the score. Combining impacts across documents resulted in a reduction to 34 impacts.

Of the 8 categories, Recreation was only coded for two impacts and therefore recoded to the Health & Wellbeing criterion, while Housing was only coded once, and therefore recoded to the Economic Effects criterion.

With no further reduction possible without reducing accuracy, the remaining six criteria were chosen as the basis for the analysis. Box 8 gives an overview of criteria and the impacts they are comprised from, ordered with the criteria which are positive for Lynetteholmen first.

3.2.1 Criteria Set Validity

For the set of criteria to be valid for an MCDA, they must be complete and exhaustive, non-redundant, and must satisfy the Mutual Preferential Independence (MPI) assumption (Belton & Stewart, 2002, pp.57–58; Mouter et al., 2020b, p.245).

Given that the criteria chosen are based on the three impact assessment documents which comprise the publicly available decision basis for the Lynetteholmen Project, it would perhaps be reasonable to consider them exhaustive. This may not be the case, however. Two of the central arguments in favor of Lynetteholmen – Storm Surge Protection and Soil Deposits – are not evaluated in any impact assessment documents.

Since neither of these impacts are included in the impact assessments, but both must be assumed to be positive impacts for the Lynetteholmen project, excluding them unfairly disadvantages it compared to the base scenario, in which storm surge protection and soil deposits would require other (presumably costly) solutions which are unaccounted for. To solve this issue and ensure exhaustiveness, I use 2 different sets of criteria, one in which I only keep the six criteria based on the EIA, SEA and CBA, and one in which I add both impacts as criteria, running the analysis with eight criteria. I will return to these choices in section 3.2 Scoring.

Criterion	Description	Impacts
Economic Effects	The direct economic impacts of the construction and operation of the Lynetteholmen project.	1. Operational Costs. 2. Sale of Land. 3. Material Goods. 4. Tourism Infrastructure. 5. Sailing & Nautical Conditions. 6. Housing and Business. 7. Construction Costs.
Traffic	The effects on traffic in Copenhagen, including economic benefits in the form of reduced travel times for both drivers and public transit users.	1. Other Infrastructure. 2. User Effects (lower travel times). 3. Capacity Challenges. 4. Traffic Safety. 5. Traffic Conditions.
Conservation	Conservational risks associated with the construction of Lynetteholmen, not including environmental effects.	1. Protected Cultural Heritage. 2. Protected Areas. 3. Archaeological Sites. 4. Landscape/Appearance.
Environmental Effects	Effects on the surrounding environment, primarily associated with the construction processes. Not including CO2-emissions or other climate measures.	1. Contaminated Soil. 2. Benthic Fauna and Vegetation. 3. Flora and Fauna. 4. Geology. 5. Ocean Floor Sediment. 6. Maritime Mammals. 7. Ocean Water Quality. 8. Vibrations.
Health and Wellbeing	Effects which directly impact humans, either through health or through wellbeing. The negative impacts are primarily associated with construction, while positive impacts are primarily during the operational phase.	1. Groundwater. 2. Population and human's health. 3. External Effects (noise and air pollution). 4. Air Quality. 5. Noise. 6. Recreative Areas.
Resource Use	Resources used and waste produced by the Lynetteholmen project, including CO2-emissions.	1. Trash. 2. Energy Use. 3. Climate. 4. Raw Materials.

Box 8: The six assessment criteria for the Lynetteholmen case and their contained impacts.

Although some may argue that Resource Use, Conservation, and Environmental Effects are closely related, I do not find cause to consider them overlapping or redundant. It is possible to imagine a decision-maker who would put great stock into reducing CO2 emissions (Resource Use) but less so into preserving the coastline or cultural heritage sites. Thus, it is necessary to keep these criteria seperated so-as to be able to simulate such a scenario (and aid decision-making based on those values). As for overlap, there is a single impact from Conservation – *Protected Areas* – which is possibly associated with impacts from Environmental Effects, as the areas' protected status could be violated by environmental effects. A closer reading of the document shows that the risk to protected areas is primarily their placement near the building sites of the planned metro, meaning the association between Environmental Effects (which is mostly oceanic) and Conservation is minimal at worst.

The MPI states that the trade-off between any two criteria (and their contained impacts) must be independent of the performance level on any third criterion (Belton & Stewart, 2002, p.57). Testing for the MPI is important in the case of eliciting weights from stakeholders or decision-makers, where some participants may base their scores and preferences on assumptions in other criteria. Since the assessments in the EIA, SEA and EIR are conducted without reference to other impacts, there are no indications that the MPI is violated in this case.

3.3 Scoring

With the criteria established, each alternative needs to be scored on them, which requires a scoring regime to compare criteria. To satisfy computational needs, scores must be interval scale (Cinelli et al., 2020, p.5).

Scores can be assigned on a local scale or a global scale. Scoring locally, each alternative is scored relative to one another, typically assigning the highest scoring alternative on any criterion a 100 and other alternatives the relevant percentage (Barfod & Leleur, 2014, p.12). Scoring globally, the end points (both negative and positive) are designated without direct reference to the alternatives, by conceptualizing the best and worst possible performance, and then alternatives are scored relative to the end points (Barfod & Leleur, 2014, p.12).

3.3.1 Assigned Scores

I give each impact a score between -3 and +3, based upon the assessment in the relevant document(s), so that a large negative effect = -3, a moderate negative effect = -2, etc. Then I sum up the scores of each impact to arrive at the aggregate category scores (Box 9).

In practical terms, the MAVT calculations require all scores to be positive. Instead of using negative numbers, the code I use defines whether a criterion is "beneficial" and at a later stage adds those which are beneficial while subtracting those which are not from the final score. As such, all scores are technically positive (non-beneficial). I report them as negative for ease of understanding, and because that is the impact they will have on the final aggregated score.

Criterion	Impacts	Scores	Total Score
Economic Effects	1. Sale of Land.	+3	**+1**
	2. Housing and Business.	+3	
	3. Tourism Infrastructure.	+1	
	4. Construction Costs.	-3	
	5. Operational Costs.	-1	
	6. Material Goods	-1	
	7. Sailing & Nautical Conditions.	-1	
Traffic	1. User Effects	+3	**+5**
	2. Other Infrastructure.	+1	
	3. Capacity Challenges	+1	
	4. Traffic Safety.	+1	
	5. Traffic Conditions.	-1	
Conservation	**1. Storm Surge Protection*.**	+3	**-6**
	2. Protected Cultural Heritage.	-3	
	3. Protected Areas.	-3	
	4. Archaeological Sites.	-2	
	5. Landscape/Appearance.	-1	
Environmental Effects	1. Benthic Fauna and Vegetation.	-2	**-11**
	2. Flora and Fauna.	-2	
	3. Vibrations.	-2	
	4. Contaminated Soil.	-1	
	5. Geology.	-1	
	6. Ocean Floor Sediment.	-1	
	7. Maritime Mammals.	-1	
	8. Ocean Water Quality.	-1	
Health and Wellbeing	1. External Effects.	+1	**-4**
	2. Recreative Areas.	+1	
	3. Groundwater.	-2	
	4. Noise.	-2	
	5. Health.	-1	
	6. Air Quality.	-1	
Resource Use	**1. Soil Deposits*.**	+3	**-5**
	2. Trash.	-2	
	3. Energy Use.	-2	
	4. Climate.	-2	
	5. Raw Materials.	-2	

Box 9: Translated scores for each impact and summed scores for each criterion.
**Storm Surge Protection and Soil Deposit impacts not based on EIA, SEA or CBA.*

For the CBA, I use a simple relative approach to scoring, where the largest impact (Construction Costs – *Anlæg*) is scored as -3, and other impacts are scored in relation to that. Thus, User Effects (*Bruger Effekter*) and Land Sale (*Grundsalg*) are both scored at +3, whereas External Effects (*Eksterne Effekter*) is scored at +1, etc.

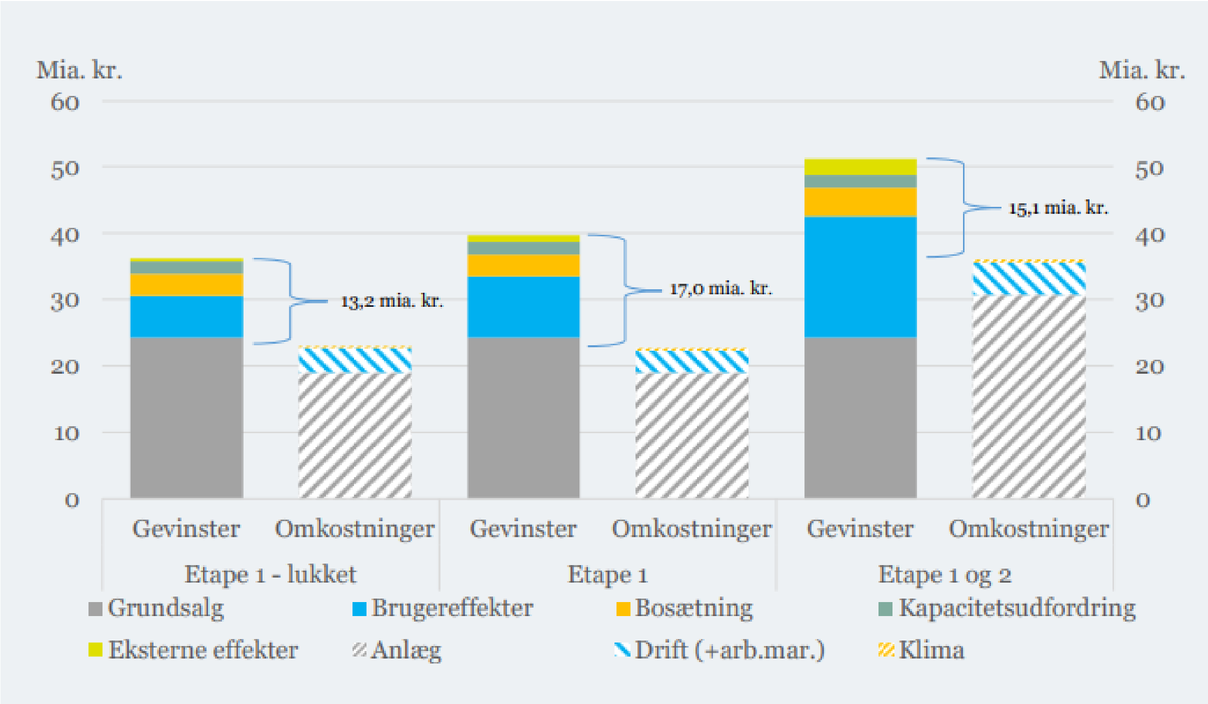

Figure 3: CBA results figure from (Transportministeriet, 2022c, p.15). I analyze only the third scenario, which is the one currently planned to be enacted.

However, since the CBA is reported in monetary units, transforming those numbers into scores between +3 and -3 is a fundamentally arbitrary exercise, as there is no clear definition for how much money a small, moderate or significant amount is. Figure 3, lifted from the CBA report, shows the relevant figures. Translating the results of the CBA to the +3/-3 scheme in an objective manner is not possible, and while integrating CBA results into MCDA is widely discussed in the literature (Barfod & Leleur, 2014; Gühnemann et al., 2012), there is no established procedure to do so. As such, it is entirely possible that a higher or lower score (+5/-5 for instance) would give a better representation of the relative importance of the impacts calculated in the CBA.

3.3.2 Pro-Lynetteholmen Bias

To mitigate this weakness, I have chosen to generally privilege the Lynetteholmen project when scoring economic issues. For instance, the choice of scoring both Land Sale and User Effects as +3, despite them being DKK 5 billion lower than Construction Costs. By privileging economic aspects with higher scores, I attempt to pre-empt the critique that I am undervaluing the CBA in assigning my scores.

Despite privileging economic aspects, the Economic Effects criterion has a score of only +1, creating a discrepancy with the CBA which projects DKK 15 billion surplus. However, a large part of the benefits calculated in the CBA are attributed to User Effects, meaning time saved by virtue of better traffic conditions. In purely monetary terms, the construction costs exceed the revenue from sale of land. Since I have coded Traffic as its own criteria, it stands to reason that Economic Effects would not have a high score.

In Section 4.4 of the analysis, I run some tests in which I increase the score of Economic Effects. If one is of the opinion that the CBA should provide a larger contribution to the scoring, consider the inflation of Economic Effects as an example of an alternate scoring based on the CBA.

3.3.3 Soil Deposit and Storm Surge

As mentioned above, two positive externalities of the Lynetteholmen project, Soil Depositing and Storm Surge protection, are not included in the EIA, SEA or CBA. If these are excluded, Lynetteholmen will be disadvantaged when compared to the base scenario. To examine the flexibility of the MCDA approach, I tackle this by testing two separate models.

In model 1, Soil Deposit is added as an impact under the Resource Use criterion and Storm Surge Protection is added as an impact under the Conservation criterion. Both impacts are given a +3 score since they are positive externalities of the Lynetteholmen project and are deemed to be important. See Box 9 for the final scores.

In model 2, I add each of them as their own criterion, duplicating the scores and number of impacts of Traffic (+5 total score with 5 impacts). This choice of scoring is, again, largely arbitrary. I have based my choice of scoring here on the public comments' documents, where interested parties offered questions and comments to the SEA (Transportministeriet, 2023). In that, some organizations comment that the proposed solution to these issues is adequate but that they could also have been accomplished through other solutions (which the traffic ministry agrees with), leading me to give both criteria a mid-level score.

Thus, we arrive at model 1 with 6 impacts (2 of which are positive for Lynetteholmen) and model 2 with 8 impacts (4 of which are positive for Lynetteholmen).

3.3.4 Score Transformations

The scores given in Box 9 have one additional issue: They are highly contingent on the number of impacts contained within. For instance, Environmental Effects, which contains 8 impacts, has a lower score than Conservation, which only contains 4 impacts, despite the Conservation impacts being scored lower on average. This difference could either be an accurate representation of the importance of the category – since its impacts cover a broad range – or it could simply be a bias introduced by my choices when creating the criteria.

Similarly, while it is reasonable to assume that the impact of between Lynetteholmen and the base scenario is larger on the Environmental Effects criterion than on the Economic Effects criterion, there is no guarantee that it is 10 times as large, as the assigned scores suggest.

To overcome these challenges, I choose to transform the score three times, creating four sets of scores, each with their advantages and disadvantages.

1. To mitigate issues of scale, I transform the assigned scores using the natural logarithm:

$$\ln(assigned) = \ln(v + 1) \tag{1}$$

where v is the assigned score, thereby reducing the importance of larger scores relative to smaller ones.

If the scores I have reported as negative were actually treated as negative numbers, this would not be possible. However, by keeping the scores positive and only later subtracted in the case of non-beneficial criteria, I can take the natural logarithm of each score. This process means that the distance to 0 remains the same whether a score is beneficial or not.

Importantly, I am actually taking the natural logarithm of the score +1, rather than the score itself. This is necessary because ln(0) is undefined, meaning I cannot perform the transformation on the base scenario where all scores are 0. By adding 1 to the assigned score before transformation, the base scenario receives a score of ln(1) = 0 on all criteria, while each of the Lynetteholmen scores remains a positive non-zero number.

Replacing a true log transformation – ln(x) – with a log-like transformation – ln(x+c) – is a well-established solution for dealing with ln-transformations of variables including 0 (Chen & Roth, 2022, p.2). This procedure should be applied cautiously, as it essentially rescales the variable, increasing low values much more than high values (Chen & Roth, 2022, p.7). Because the purpose of the logarithmic transformation is to amplify the relative importance of lower-scoring criteria, I find the use of an ln(x + c) transformation to be justified. At the same time, this approach introduces a scale-dependent bias, which must be considered when interpreting the results.

2. To mitigate issues of more or fewer impacts, I calculate the average scores:

$$Proportional = \frac{v}{n} \tag{2}$$

where v the assigned score is and n is the number of impacts in the criterion.

3. Finally, I combine the two:

$$\ln(Proportional) = \ln\left(1 + \frac{v}{n}\right) \tag{3}$$

The result is eight score permutations, four for model 1 with six criteria (Box 10) and four for model 2 with eight criteria (Box 11). Note again that the scores reported here as negative are technically treated as positive until the last stage of the analysis.

Six Criteria	Assigned	ln(Assigned)	Proportional	ln(Proportional)
Economic Effects	+1	+0.69	+0.14	+0.13
Traffic	+5	+1.79	+1	+0.69
Conservation	-6*	-1.95	-1.2	-0.79
Environmental Effects	-11	-2.48	-1.38	-0.87
Health & Wellbeing	-4	-1.61	-0.67	-0.51
Resource Use	-5*	-1.79	-1	-0.69

Box 10:Four score permutations for the model with 6 criteria.
** +3 added to Conservation from Storm Surge Protection Impact and Resource Use from Soil Deposits Impact.*

Eight Criteria	Assigned	ln(Assigned)	Proportional	ln(Proportional)
Economic Effects	+1	+0.69	+0.14	+0.13
Traffic	+5	+1.79	+1	+0.69
Soil Deposits	+5	+1.79	+1	+0.69
Storm Surge Protection	+5	+1.79	+1	+0.69
Conservation	-9	-2.3	-2.25	-1.18
Environmental Effects	-11	-2.48	-1.38	-0.87
Health & Wellbeing	-4	-1.61	-0.67	-0.51
Resource Use	-8	-2.2	-2	-1.1

Box 11: Score permutations for the model with 8 criteria. Storm Surge Protection and Soil Deposits added as full criteria.

Throughout the analysis, I will be examining all eight permutations. Each score has a particular bias, with the *Assigned* scores undervaluing very low scores, while *ln(Assigned)* overvalues them. Similarly, the *Proportional* scores overvalue agreement in the contained impacts (4 impacts with +3 gives a much higher score than 6 impacts with +2). For this reason, I generally lend most credence to those conclusions that persist across multiple permutations. Following the analysis, I will discuss my use of different scoring permutations further.

3.3.5 Linearity

One final note on the scores I use. This scoring regime assumes linearity in the value curves of the criteria. If this assumption is not true (for instance, if a certain level of groundwater quality loss is relatively unimportant, but a higher level poses serious risks to health and safety) then the MCDA analyst must uncover the functional forms and include these in the model (Barfod & Leleur, 2014, p.13; Belton & Stewart, 2002, pp.123–124).

One of the goals of conducting environmental impact assessments is to ensure that there are no legal or environmental barriers that are irreversibly exceeded. Neither the EIA nor the SEA finds any concerns of this level. Given this, and because there are no other indicators of nonlinearity, I do not find cause to assume that the value curves are problematically non-linear. However, field-specific experts might disagree with this judgement, and any MCDA-process carried out within the civil service should consider this possibility carefully.

3.4 Weights

With the criteria chosen and the scores assigned, it is now possible to compare the Lynetteholmen project to the base scenarios score of 0 across the board. This is where the key to MCDA comes in – the weights. In MCDA, it is not assumed that each of the criteria is equally important. On the contrary, weights are constructed based on stakeholder and/or decision-maker preferences, to ensure that the relative importance given to each criterion is in line with the goals and visions that govern the project (Barfod & Leleur, 2014, p.17; Cinelli et al., 2020, p.1).

As the Lynetteholmen project has already been chosen (and there are not multiple alternatives to choose between), my approach is a bit different. Borrowing an idea from Mazurek & Strzałka (2022) I return to the question *Under which conditions does the simplified MCDA favor enacting the Lynetteholmen plan over not doing so?*

Put another way: *What weights must be assigned to the criteria for Lynetteholmen to get a total score greater than 0?*

3.4.1 Multi-Attribute Value Theory

I use the most straightforward – and most widely used – understanding of the relationship between the criteria, Multi-Attribute Value Theory (MAVT) (Barfod & Leleur, 2014, p.24; Morton, 2018, p.1). MAVT is one of several compensatory MCDA approaches, meaning it considers each criterion interchangeable, in the sense that a positive score in one criterion may offset a negative score in another (Dean, 2020, p.179; Digkoglou et al., 2024, p.4). In this understanding, weights are defined as trade-off coefficients or substitution rates – the amount of units one criterion must increase to offset a 1 unit decrease in another (Belton & Stewart, 2002, pp.92–93).

Considering the criteria scores interchangeable allows MAVT practitioners to make straightforward recommendations based on a linear weighted additive model (Dean, 2020, p.176):

$$Overall\ Value\ V(a) = \sum_{i=1}^{n} w_i * v_i(a) \qquad 4$$

Where a is the alternative, w is the weight, i is the criterion, and v is the score.

Allowing criteria to compensate for one another allows MAVT practitioners to give a single-value recommendation between multiple alternatives, keeping interpretation of the results simple for decision-makers with little or no technical understanding.

Since I am using four different score permutations, each model will result in four different aggregate scores – V – based on the four different score permutations – v – derived from my assigned scores and equation 1-3.

On the surface, the interchangeability of criteria is closely related to the monetization process carried out in CBA. In both methods, the criteria/impacts are converted into a comparable unit and considered fully interchangeable. In practice, however, the use of weights differentiates the methods substantially. Whereas the accounting in CBA is final and supposedly objective, the criteria in MAVT are each given subjective weights, thus altering their influence on the final analysis. This gives the analyst the ability to tailor the recommendation to the specific problem and the preferences of the decision-maker, as well as ensuring a higher level of transparency, while keeping the simple *highest scoring alternative is best* interpretation of CBA.

3.4.2 Varying the weights

To explore the question of which weights result in Lynetteholmen being favored, I use a series of weighting schemes, each of which will be explained as they come up in the analysis. To construct weighting schemes, I overweight certain criteria by some chosen percentage. For instance, one weighting scheme may overweight Economic Effects and Traffic by 300 %, meaning the scores of those criteria contribute 3 times as much as the scores of other criteria (a weight of 0.33 vs. 0.083 for other criteria in the 6 criteria permutations).

For ease of interpretation and for computational considerations, the weights are normalized to fall between 0 and 1 and so that they sum to 1 (Barfod & Leleur, 2014, p.25).

My calculations, including weightings, are done in R. The R code used for calculations and simulations is found in “Appendix 2 – R Code”.

3.5 Sensitivity

For any MCDA analysis, the scores and (especially) the weights are insecure. Depending on elicitation methods, data on criteria, and complexity of the problem, these inputs may be more or less reliable. Even following best practice, the analyst should assume that there is a margin for error which threatens the validity of their recommendation (Barfod & Leleur, 2014, p.9; Cinelli et al., 2020, p.10). In my case, the scores and weights must be assumed to be extremely unreliable, since there is no method to validate whether my translations of the results in the EIA, SEA or CBA are accurate to the authors' or other experts' assessments.

Sensitivity analysis – examining the results' sensitivity to changes in parameters – is employed to uncover and mitigate these issues.

3.5.1 Manual Variation

One method of sensitivity analysis is to vary individual important parameters to test their impact on the results. This method is useful if a single score or weight seems to be under- or over-influencing the analysis, as well as if there are specific inputs whose values are surprising compared to assumptions (Cinelli et al., 2020, p.11; Gühnemann et al., 2012, p.20).

As mentioned previously, the Economic Effects criterion score is so low that its influence on the overall analysis is nearly non-existent. For this reason, I devote a portion of the analysis to rerun tests with an inflated Economic Effects score.

Testing a series of different weighting schemes as I do could reasonably be described as a form of sensitivity analysis, in that I am testing how results and recommendations react to different weights being inputted. However, this explorative approach differs from a typical sensitivity analysis in the sense that I am not trying to validate any *original* elicited weights but rather trying to uncover the range of weighting schemes that would result in the Lynetteholmen project being recommended.

3.5.2 Monte Carlo

Manually varying inputs and seeing whether Lynetteholmen > base scenario is not enough, however. For any chosen scores and weighting scheme, it is also necessary to know how robust the outcome is to random variations in those inputs. For this, I use the Monte Carlo method.

For each combination of score permutations and weighting regimes (model), Monte Carlo runs the same model a number of times (iterations) while randomly varying either scores or weights or both within a given range of uncertainty. For my case, that means running 50.000 iterations while varying scores and weights up to 20 % and up to 50 % in either direction.

Since there is uncertainty in both scores and weights, I choose to vary both simultaneously in each simulation. This also follows the recommendation of Saltelli et al. (2019), who argue that global sensitivity analyses (varying all inputs simultaneously) is necessary to adequately test uncertainty and sensitivity in most cases (Saltelli et al., 2019, p.37). The authors furthermore suggest that Monte Carlo simulation is one of the more intuitive approaches available for global sensitivity analysis (Saltelli et al., 2019, p.34).

Mazurek & Strzałka (2022) suggest 10.000 iterations as the lower bound of iterations to reach a viable result (Mazurek & Strzałka, 2022, p.5). I ran some comparative tests with 10.000, 50.000, and 100.000 iterations, and chose 50.000 iterations as this level yielded stable results while keeping computational requirements relatively low.

The simulation draws from a random distribution within the range, meaning it is no more likely for score/weights to be drawn closer to the center than at the outer edge. If there was greater confidence in the original inputs, it would make sense to draw from a normal distribution (or similar) around the inputted scores/weights. Since I am attempting to mitigate my low confidence in the original inputs, however, I choose to draw at random from within the range (Barfod & Leleur, 2014, p.27; Mazurek & Strzałka, 2022, p.2).

Choosing how much to vary the inputs is ultimately up to the researcher and based on the confidence in the original inputs as well as the goal of the analysis. I have chosen to vary inputs by up to 20 % and 50 % in two separate simulations, thus testing for a moderate level of uncertainty as well as a high level of uncertainty.

The output of the Monte Carlo simulations gives the percentage of iterations where Lynetteholmen outperformed the base scenario (where its total score is greater than 0). Thus, when asking *How sensitive are these conclusions to changes in scores and criteria weights?*, the answer is a given percentage chance that it would persist even if inputs were randomly varied by 20 % or 50 %.

3.6 Summary

In the analysis, I combine the scores, which are based on the EIA, SEA and CBA, with a series of different weighting schemes, exploring which weights allow for Lynetteholmen to outperform the base scenario. To mitigate the uncertainty in the criteria, scores, and weights, I utilize eight score permutations and run Monte Carlo simulations to all models. Box 12 shows the steps conducted in testing each weighting regime.

Testing a Weighting Regime

1. Assign Weights

Choose which variables to overweight and by how much.

2. Calculate Aggregate Scores

For each criterion, combine the chosen weighting regime with the scores.

Sum scores (subtracting non-beneficial criteria) to find aggregate scores.

Repeat for each of the eight permutations.

3. Test Sensitivity

Vary inputs (weights and scores) by 20 % and 50 % to test stability of results.

Stable results persist when inputs are varied.

Monte Carlo simulation reports percentage of results where Aggregate Scores >0

4. Interpret

The tested weighting regime supports a recommendation of Lynetteholmen if the Aggregate Score is greater than 0.

The tested weighting regime is stable if this result persists across score permutations and the Monte Carlo probabilities are high.

5. Disaggregate

When a weighting regime supports a recommendation of Lynetteholmen, the model is analyzed further to examine the relative importance of each criterion for that result.

Box 12: Steps of Analysis for each tested Weighting Regime.

4. Analysis

In a typical MCDA analysis, the analysis would combine the scores for each alternative with the weights elicited (based on either stakeholder, expert, or analyst inputs) to produce a policy recommendation between the relevant alternatives. Since both the scoring and weighting are possibly contested, the analyst would usually conduct a series of sensitivity tests. The tests show how robust the conclusion (recommendation) is, under which parameters it holds, and, crucially, which criteria have been most influential in arriving at the conclusion.

My analysis takes a more exploratory approach. To find the policy priorities underpinning the recommendation of the Lynetteholmen project, I examine a series of different weighting schemes: Unweighted, Single Criterion Bias, and Policy Regimes in subsections 4.1-4.3. Then, in subsection 4.4, I rerun the analysis with a changed score set in which Economic Effects is purposefully inflated compared to my original scoring.

For each model, the central question is whether Lynetteholmen scores better than the base scenario, i.e. whether enacting Lynetteholmen will *overall* be better (given the included criteria and chosen weights) than not doing so. For a given model, the answer to this question is yes if the total aggregated score of Lynetteholmen is greater than 0.

I include the tables, graphs and figures that are most relevant to analysis. An expanded list of tables, graphs and figures is found in "Appendix 3 – Tables and Graphs". Box 13 on the following page clarifies the central terms used throughout the analysis.

Analysis Terminology

Alternatives

MCDA compares multiple possible solutions or policies to the problem at hand. In this thesis, the two alternatives are Lynetteholmen and a base scenario where all scores are set to 0.

Criteria

The alternatives are compared based on a series of criteria which are scored and given different weights to arrive at the alternative's relative performance. In this thesis, I use up to eight different criteria.

Permutation

The analysis uses two criteria sets (one model with six criteria and one model with eight criteria) and four different transformations – *Assigned, ln(Assigned), Proportional, ln(Proportional)* – of the scores for each criteria set. I use permutations to refer to the resulting eight different score sets.

Iteration

The Monte Carlo simulation method runs 50.000 iterations in which scores and weights are varied randomly within a set percentage range. When the Monte Carlo result is 0 %, that means all iterations favor the base scenario. When they are 50 %, that means half favor Lynetteholmen and half the base scenario. When the Monte Carlo result is 100 %, then all iterations favor Lynetteholmen, meaning that the random variation does not challenge the result.

Box 13: Central concepts of the analysis

4.1 Unweighted

Running the analysis with equal weights results in the base scenario dominating the Lynetteholmen project. Across both models, Lynetteholmen receives large negative scores in every permutation (Table 1 and 2), meaning the project is assessed as worse than no intervention being enacted.

6 - Equal Weights

	Assigned	ln(Assigned)	Proportional	ln(Proportional)
Score	-3.333	-0.892	-0.518	-0.34
Top Contributor	Environmental Effects (34.4%)	Environmental Effects (24.1%)	Environmental Effects (25.6%)	Environmental Effects (23.6%)
Bottom Contributor	Economic Effects (3.1%)	Economic Effects (6.7%)	Economic Effects (2.6%)	Economic Effects (3.5%)
Monte Carlo 20 %	0 %	0 %	0 %	0 %
Monte Carlo 50 %	0 %	0 %	0 %	0 %
Positive Weights	Economic Effects = 0.167	Traffic = 0.167		
Negative Weights	Conservation = 0.167	Environmental Effects = 0.167	Health and Wellbeing = 0.167	Resource Use = 0.167

Table 1: Unweighted analysis with 6 criteria. The base scenario outperforms Lynetteholmen in every score permutation, with Environmental Effects contributing most to the results.

8 - Equal Weights

	Assigned	ln(Assigned)	Proportional	ln(Proportional)
Score	-2	-0.316	-0.395	-0.182
Top Contributor	Environmental Effects (22.9%)	Environmental Effects (16.9%)	Conservation (23.8%)	Conservation (20.1%)
Bottom Contributor	Economic Effects (2.1%)	Economic Effects (4.7%)	Economic Effects (1.5%)	Economic Effects (2.2%)
Monte Carlo 20 %	0 %	0.1 %	0 %	0 %
Monte Carlo 50 %	1.8 %	13.4 %	1.7 %	5.9 %
Positive Weights	Economic Effects = 0.125	Traffic = 0.125	Soil Deposit = 0.125	Storm Surge = 0.125
Negative Weights	Conservation = 0.125	Environmental Effects = 0.125	Health and Wellbeing = 0.125	Resource Use = 0.125

Table 2: Unweighted analysis with 8 criteria. The base scenario outperforms Lynetteholmen in every score permutation, with Environmental Effects and Conservation contributing most to the results.

Comparing the scores between Table 1 and 2 shows that the 8 criteria analysis is generally more favorable towards Lynetteholmen (the scores are closer to zero across the board), but not enough to change the overall result.

Results of the Monte Carlo simulation show that even varying scores and weights by 50 % only results in at best a 13.4 % probability that Lynetteholmen outperforms the base scenario, and then only in the most favorable score permutation.

Making a recommendation here is straight-forward. If each criterion is weighted equally, the Lynetteholmen project cannot be recommended.

4.2 Single Criterion Bias

To examine the criteria one by one, I use an overweighting of 500 %, where a single criterion is given 5 times the weight of each other criterion (which are all weighted equally).

The results are mostly predictable: Whichever criterion is overweighted dominates the analysis, and Lynetteholmen is recommended in the models where the overweighted criterion contributes positively to its score. For instance, overweighting Storm Surge Protection favors Lynetteholmen, with the Storm Surge criterion contributing 36.8-41 % to the result (Table 3).

8 - Storm Surge Bias

	Assigned	ln(Assigned)	Proportional	ln(Proportional)
Score	0.333	0.386	0.07	0.108
Top Contributor	Storm Surge (36.8%)	Storm Surge (41%)	Storm Surge (37.2%)	Storm Surge (40%)
Bottom Contributor	Economic Effects (1.5%)	Economic Effects (3.2%)	Economic Effects (1%)	Economic Effects (1.5%)
Monte Carlo 20 %	77.5 %	99.9 %	79 %	98.1 %
Monte Carlo 50 %	59.7 %	86.7 %	60.5 %	76.5 %
Positive Weights	Economic Effects = 0.083	Traffic = 0.083	Soil Deposit = 0.083	Storm Surge = 0.417
Negative Weights	Conservation = 0.083	Environmental Effects = 0.083	Health and Wellbeing = 0.083	Resource Use = 0.083

Table 3: Storm Surge overweighted by 500 % with 8 criteria. Lynetteholmen outperforms, but with weak Monte Carlo probabilities in some permutations at 50 % variation.

There is one notable exception to this pattern. The Economic Effects criterion, with its assigned score of only 1, does not dominate the results, and only causes Lynetteholmen to outperform the base scenario in 1 of 8 score permutations, and then only by a tiny margin (Table 4).

8 - Economic Effects Bias

	Assigned	ln(Assigned)	Proportional	ln(Proportional)
Score	-1	0.019	-0.217	-0.078
Top Contributor	Environmental Effects (21.2%)	Economic Effects (19.8%)	Conservation (22.5%)	Conservation (18.5%)
Bottom Contributor	Health and Wellbeing (7.7%)	Health and Wellbeing (9.2%)	Health and Wellbeing (6.7%)	Health and Wellbeing (8%)
Monte Carlo 20 %	0 %	58.6 %	0 %	0.6 %
Monte Carlo 50 %	6.6 %	53 %	4.5 %	16.9 %
Positive Weights	Economic Effects = 0.417	Traffic = 0.083	Soil Deposit = 0.083	Storm Surge = 0.083
Negative Weights	Conservation = 0.083	Environmental Effects = 0.083	Health and Wellbeing = 0.083	Resource Use = 0.083

Table 4: Economic Effects overweighted by 500 % with 8 criteria. Lynetteholmen only outperforms in one permutation, while other criteria contribute more in other score permutations.

On one hand, this result shows the importance of the scoring stage, as the Economic Effects criterion becomes almost irrelevant to the broader analysis based on the low score. On the other hand, the correct interpretation of a score of 1 is that on the criterion of Economic Effects, Lynetteholmen is only very slightly better than the base scenario. As such, the model correctly values other criteria in terms of a comparison between the alternatives. Even if Economic Effects is the most important criterion, if there is little to no difference between alternatives on that criterion, it should not dominate the analysis.

Plotting the contributions of each criterion to the final score in this model (Figure 4) clarifies the low contribution of Economic Effects in most permutations. Figure 4 also shows how the *ln(Assigned)* permutation may be biased in favor of low-scoring results by significantly reducing the influence of differences between the scores. The range of contributions from the unweighted criteria is lower in this score permutation than in the others (within 5 percentage points rather than 10-15 percentage points). Because the scores in the *ln(Assigned)* permutations are compressed (and because I used an ln(x+1) transformation), the weighting regime influences this permutation more heavily compared to other permutations.

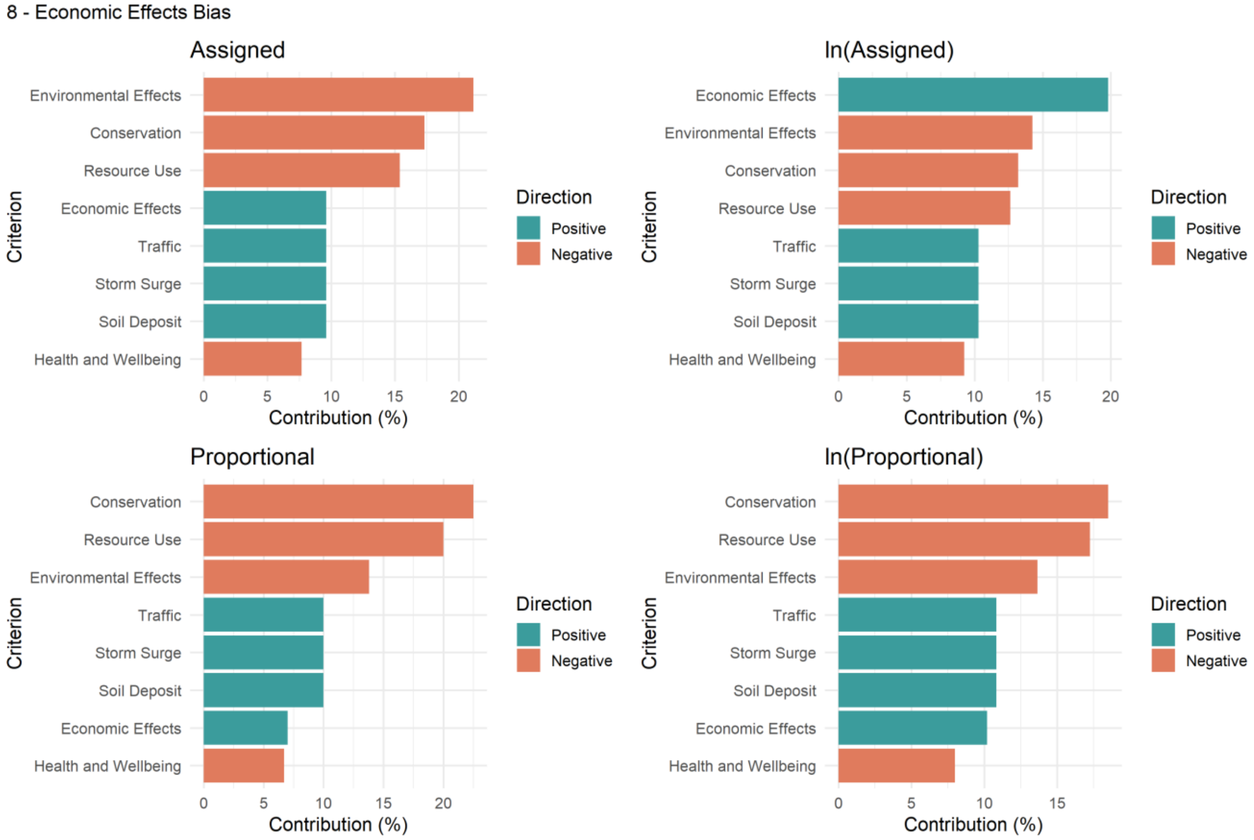

Figure 4: Tornado Plot with Economic Effects overweighted by 500 % with 8 criteria. Despite overweighting, Economic Effects contributes only ≈ 10 % to the results of most permutations, and 20 % to the ln(Assigned) permutation.

I will return to the low score of Economic Effects in section 4.4.

4.3 Policy Rationales

Given that the unweighted analysis showed a strong negative score across the board for Lynetteholmen, the next relevant question is *which weighting schemes produce a recommendation in favor of Lynetteholmen?*

Considering this question within a policy context, I devised three policy rationales which overweight criteria that realistically fit together in a possible political vision/prioritization:

a) **Human Centered Rationale**, which overweights Economic Effects, Traffic, and Health and Wellbeing.

b) **Economic + Climate Rationale**, which overweights Economic Effects, Traffic, Storm Surge Protection, and Resource Use.

c) **Economic Rationale**, which overweights Economic Effects and Traffic.

These three rationales represent realistic (albeit stylized) potential policy positions based on the criteria, all of which are weighted more towards the criteria on which the Lynetteholmen project has positive scores. They are quite similar, since any rationale which does not include the Traffic criterion makes it near-impossible for Lynetteholmen to get a positive overall score.

For each rationale, I overweight the criteria by 300 and 500 %. For simplicity I overweight each included criterion equally, but it is just as possible to overweight some criteria more than others.

4.3.1 Human Centered Rationale

This rationale overweights the Economic Effects and Traffic criteria (positive for Lynetteholmen) as well as the Health & Wellbeing criterion (negative for Lynetteholmen), showing results if stakeholders or decisionmakers value short-term human concerns over environmental and climate concerns. Generally, the results do not favor Lynetteholmen, with 0 permutations being positive at 300 % overweighting and only 1 being positive at 500 % overweighting (Table 5).

8 - Human Centered Rationale 500 PCT.

	Assigned	ln(Assigned)	Proportional	ln(Proportional)
Score	-0.4	0.048	-0.064	-0.011
Top Contributor	Traffic (28.4%)	Traffic (28.9%)	Traffic (30%)	Traffic (30.9%)
Bottom Contributor	Economic Effects (5.7%)	Soil Deposit (5.8%)	Economic Effects (4.2%)	Economic Effects (5.8%)
Monte Carlo 20 %	9.7 %	66.3 %	13.7 %	38.9 %
Monte Carlo 50 %	29.5 %	56.3 %	32.8 %	44.6 %
Positive Weights	Economic Effects = 0.250	Traffic = 0.250	Soil Deposit = 0.050	Storm Surge = 0.050
Negative Weights	Conservation = 0.050	Environmental Effects = 0.050	Health and Wellbeing = 0.250	Resource Use = 0.050

Table 5: Human Centered Rationale overweighted 500 % with 8 criteria. Lynetteholmen outperforms in ln(Assigned), with weak Monte Carlo probabilities in ln(Assigned) and ln(Proportional).

The tornado diagram shows the large contributions from the Traffic and Health & Wellbeing criteria that govern this result (Figure 5).

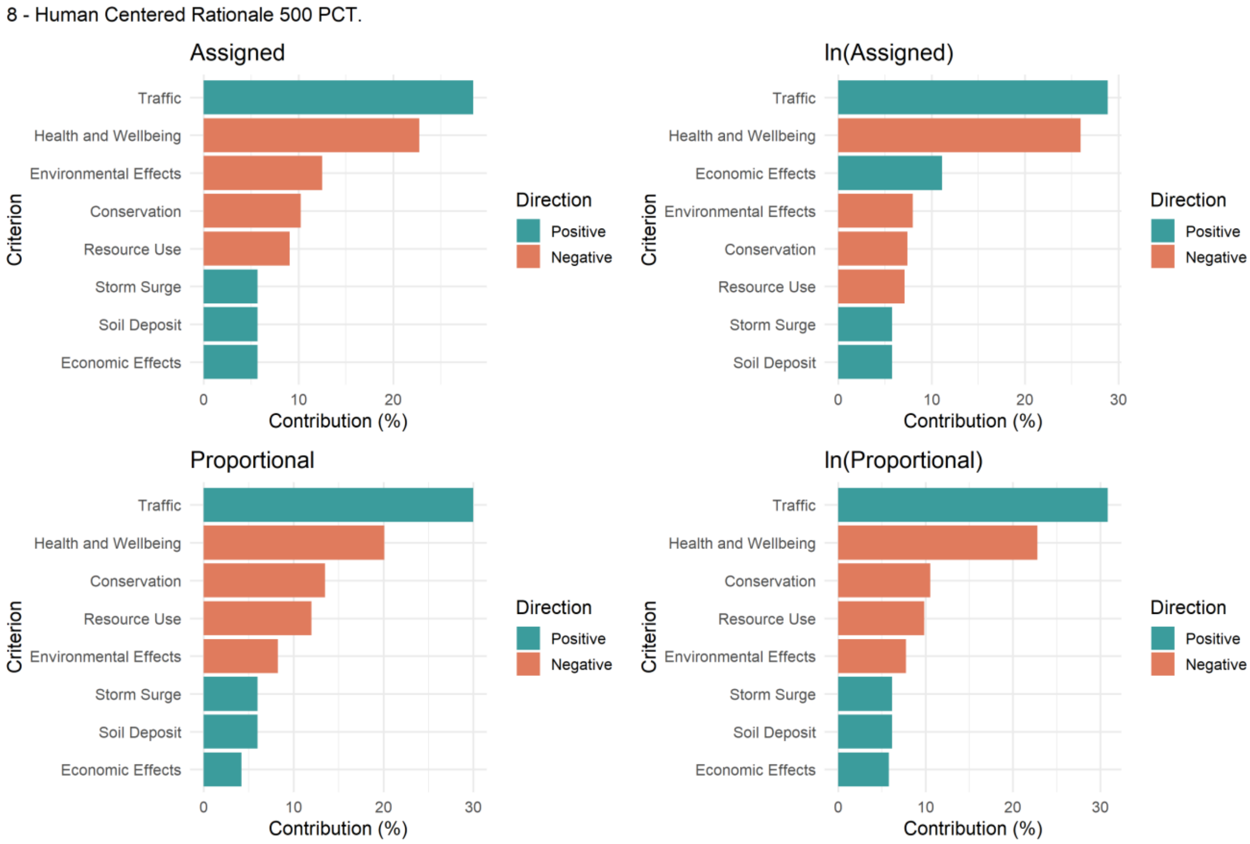

Figure 5: Tornado Plot of Human Centered Rationale with 8 criteria and 500 % overweighting. Traffic and Health & Wellbeing contribute significantly more than other criteria.

These results are very unstable, which can be visualized through histograms of the Monte Carlo simulation (Figure 6). When inputs are varied by 50 %, about a third of iterations cross the 0-line, meaning that there is a 30 % chance of Lynetteholmen being favored and a 70 % chance of the base scenario being favored.

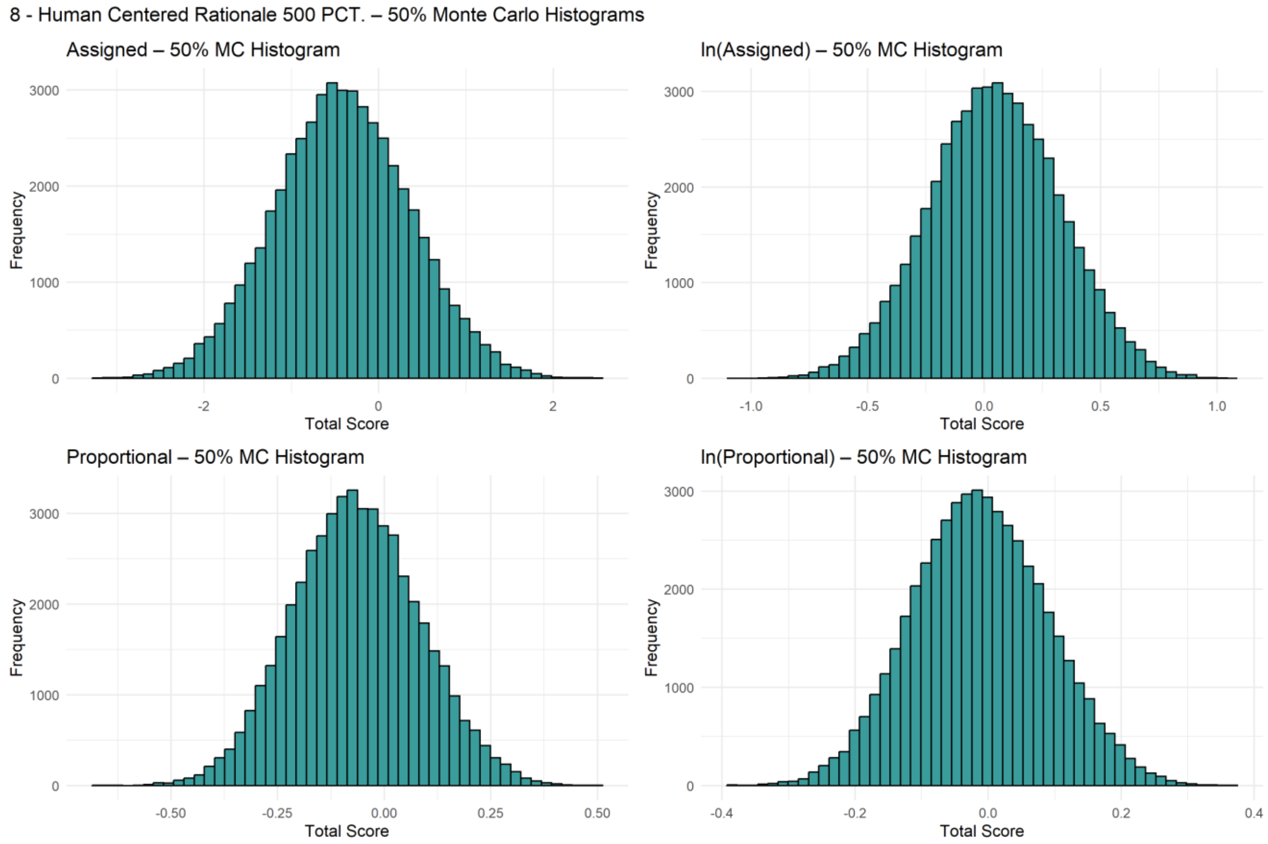

Figure 6: Monte Carlo Histogram with 50 % variation. All four permutations exhibit high levels of instability, with ≈ 30-45 % of iterations crossing the 0-line.

The Human Centered Rationale cannot clearly recommend Lynetteholmen over the base scenario but likewise cannot clearly recommend the base scenario over Lynetteholmen – It is not clear whether enacting Lynetteholmen would be better than no intervention.

For a building project of this size and scope, however, it should be expected to have a much stronger recommendation, especially given the uncertainty and risks associated. As such, I find the Human Centered Rationale to be insufficient as the basis of the Lynetteholmen project.

4.3.2 Economic + Climate Rationale

This rationale overweights the Economic Effects, Traffic, and Storm Surge criteria (positive for Lynetteholmen) as well as the Resource Use criterion (negative for Lynetteholmen), showing results if stakeholders value economic gains but also want to mitigate sea rise impacts and limit CO2-usage (which governs 50 % of the Resource Use criterion). The results are similar to the Human Biased Rationale, albeit slightly better, with 1 permutation favoring Lynetteholmen at 300 % overweighting (Table 6) and 2 at 500 % (Table 7).

8 - Economic + Climate Rationale 300 PCT.

	Assigned	ln(Assigned)	Proportional	ln(Proportional)
Score	-0.625	0.101	-0.18	-0.04
Top Contributor	Resource Use (27.9%)	Resource Use (23.9%)	Resource Use (33.9%)	Resource Use (29.8%)
Bottom Contributor	Economic Effects (3.5%)	Health and Wellbeing (5.8%)	Economic Effects (2.4%)	Economic Effects (3.5%)
Monte Carlo 20 %	4.2 %	81.1 %	0.9 %	20.9 %
Monte Carlo 50 %	25.6 %	63.6 %	19.5 %	37.9 %
Positive Weights	Economic Effects = 0.188	Traffic = 0.188	Soil Deposit = 0.062	Storm Surge = 0.188
Negative Weights	Conservation = 0.062	Environmental Effects = 0.062	Health and Wellbeing = 0.062	Resource Use = 0.188

Table 6: Economic + Climate Rationale overweighted 300 % with 8 criteria. Lynetteholmen outperforms in ln(Assigned), but with a quite unstable Monte Carlo probability.

8 - Economic + Climate Rationale 500 PCT.

	Assigned	ln(Assigned)	Proportional	ln(Proportional)
Score	-0.167	0.24	-0.108	0.007
Top Contributor	Resource Use (32.3%)	Resource Use (27.1%)	Resource Use (38.5%)	Resource Use (33.7%)
Bottom Contributor	Health and Wellbeing (3.2%)	Health and Wellbeing (4%)	Health and Wellbeing (2.6%)	Health and Wellbeing (3.1%)
Monte Carlo 20 %	33.8 %	97.8 %	10.4 %	56.6 %
Monte Carlo 50 %	44.2 %	78.5 %	32.2 %	53.5 %
Positive Weights	Economic Effects = 0.208	Traffic = 0.208	Soil Deposit = 0.042	Storm Surge = 0.208
Negative Weights	Conservation = 0.042	Environmental Effects = 0.042	Health and Wellbeing = 0.042	Resource Use = 0.208

Table 7: Economic + Climate Rationale overweighted 500 % with 8 criteria. Lynetteholmen outperforms in both ln-transformed permutations, but with strong Monte Carlo probabilities only in ln(Assigned).

As with the Human Centered Rationale, the Monte Carlo simulation shows the instability of this model, with probabilities close to 50 %. As a reminder, a Monte Carlo result of 50 % means that there is an equal probability that Lynetteholmen or the base scenario obtains the higher aggregate score. In other words, when varying the input scores and weights, there is a high likelihood that either alternative may perform better, making it impossible to recommend one over the other.

Based on these results, the Economic + Climate Rationale also does not warrant a recommendation of Lynetteholmen over the base scenario. For Lynetteholmen to be clearly recommended, a different weighting scheme is necessary.

4.3.3 Economic Rationale

Since the previous rationales yield mixed results for Lynetteholmen at best, I turn now to a purely economic rationale, overweighting Economic Effects and Traffic. In the Economic

Rationale, Lynetteholmen outperforms the base scenario on 2 of 8 permutations at 300 % overweighting (Table 8) and on all permutations at 500 % overweighting (Table 9).

6 - Economic Rationale 300 PCT.

	Assigned	ln(Assigned)	Proportional	ln(Proportional)
Score	-0.8	-0.039	-0.083	-0.04
Top Contributor	Traffic (34.1%)	Traffic (35.2%)	Traffic (39.1%)	Traffic (38.9%)
Bottom Contributor	Economic Effects (6.8%)	Health and Wellbeing (10.5%)	Economic Effects (5.5%)	Economic Effects (7.3%)
Monte Carlo 20 %	0.9 %	36.3 %	9.5 %	18.1 %
Monte Carlo 50 %	18 %	42.6 %	28.8 %	33.9 %
Positive Weights	Economic Effects = 0.300	Traffic = 0.300		
Negative Weights	Conservation = 0.100	Environmental Effects = 0.100	Health and Wellbeing = 0.100	Resource Use = 0.100

Table 8: Economic Rational overweighted 300 % with 6 criteria. The base scenario outperforms Lynetteholmen, but with weak Monte Carlo scores in most permutations, indicating a close to equal result.

8 - Economic Rationale 500 PCT.

	Assigned	ln(Assigned)	Proportional	ln(Proportional)
Score	0.5	0.462	0.088	0.114
Top Contributor	Traffic (34.7%)	Traffic (36.4%)	Traffic (35.7%)	Traffic (37.7%)
Bottom Contributor	Health and Wellbeing (5.6%)	Health and Wellbeing (6.6%)	Health and Wellbeing (4.8%)	Health and Wellbeing (5.6%)
Monte Carlo 20 %	94.5 %	100 %	91.7 %	99.9 %
Monte Carlo 50 %	71.5 %	96.4 %	68.9 %	86 %
Positive Weights	Economic Effects = 0.312	Traffic = 0.312	Soil Deposit = 0.062	Storm Surge = 0.062
Negative Weights	Conservation = 0.062	Environmental Effects = 0.062	Health and Wellbeing = 0.062	Resource Use = 0.062

Table 9: Economic Rationale overweighted 500 % with 8 criteria. Lynetteholmen outperforms in all permutations with moderate or strong Monte Carlo probabilities.

Examining the Monte Carlo probabilities, the 300 % overweighting model is found to be quite unstable, with low confidence in some permutations at 20 % variation and very low confidence at 50 % variation.

At 500 % overweighting, the results are clearer, with multiple permutations above 80 % and all above 65 %. It is worth noting, however, that this result is still not truly stable, showing about a 30 % chance that the base scenario outperforms Lynetteholmen in the *Assigned* and *Proportional* permutations. Compared to the 90 % stability of the Equal Weights model in Table 1 and 2, the Economic Rationale allows for a recommendation of Lynetteholmen, but not necessarily a strong one.

Despite some uncertainty, the Economic Rationale is the most favorable towards Lynetteholmen, and the most likely viable rationale under the assumption that Lynetteholmen *should be* recommended. With the Traffic and Economic Effects criteria overweighted by 500 %, Lynetteholmen is recommended across score permutations and Monte Carlo variations.

As previously mentioned, MCDA should give both a recommendation and provide transparency regarding the underlying factors that provide the recommendation. Therefore, it is worth delving a bit further into the makeup of the results.

In constructing the Economic Rationale model, the Traffic criterion dominates the analysis, contributing 34.7-37.7 % at 500 % overweighting (Figure 7).

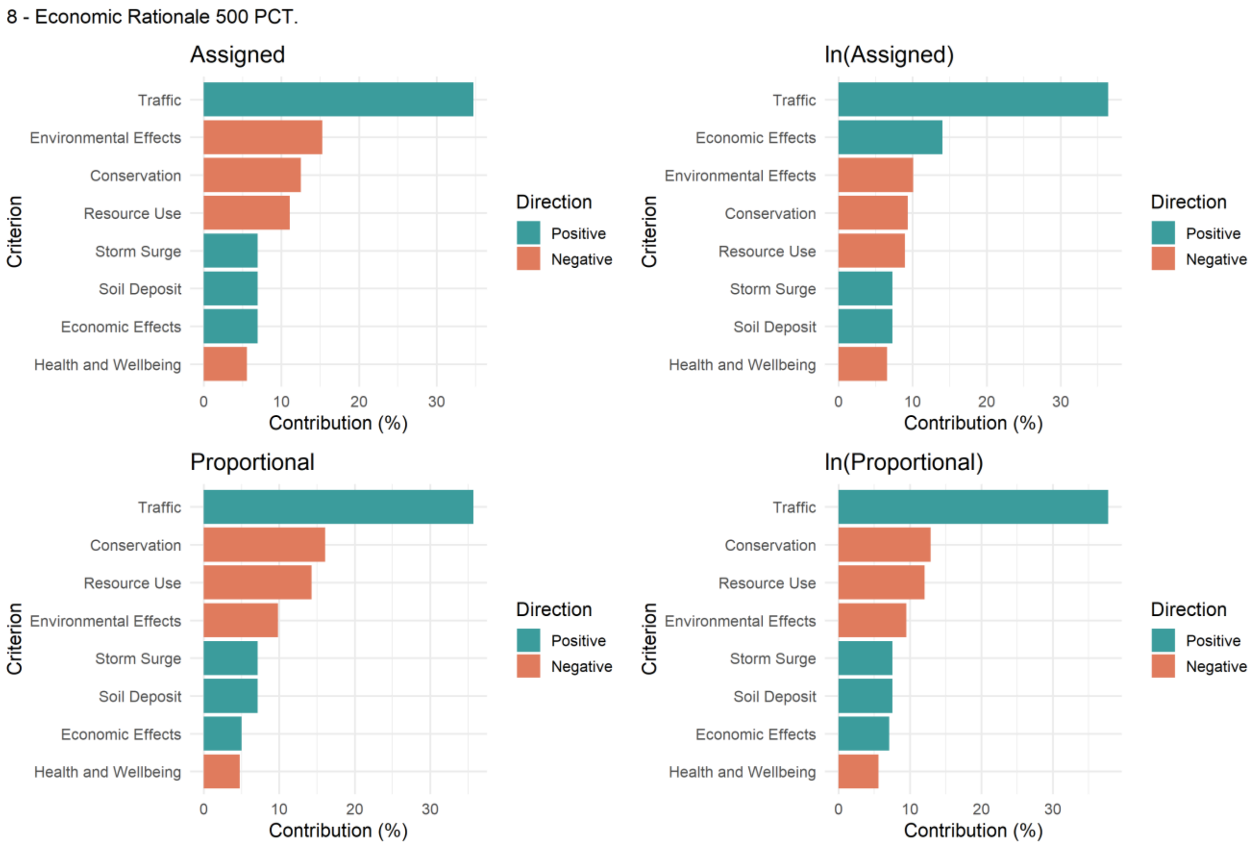

Figure 7: Tornado Plot with Economic Rationale overweighted by 500 % with 8 criteria. The Traffic criterion contributes approximately 35 % to the analysis across score permutations.

In other words, to accept the recommendation of enacting the Lynetteholmen project, one would need to value Traffic gains as at least 35 % of the overall benefits and costs among Economic Effects, Traffic Gains, Soil Depositing, Storm Surge Protection, Conservation, Environmental Effects, Health and Wellbeing, and Resource Use connected to the project.

Such a valuation is potentially accurate to decision-maker preferences, in which case the recommendation in favor of Lynetteholmen holds. However, using MCDA clarifies these priorities significantly, allowing decision-makers to consider more directly whether their preferences align with the recommendation.

4.4 Inflating Economic Effects

One possible criticism of this analysis is the potential bias and lack of reliability in my initial scoring. In MCDA, scoring is inherently contentious, as experts, analysts, and other stakeholders inevitably assign scores based on subjective judgement. Developing robust, systematic, and widely accepted scoring protocols remains a significant and unfinished challenge (Danielson, 2009, p.5).

The scores I use are an attempt at translating the data and analysis included in the EIA, SEA, and CBA into a unified framework, but it is likely that a different person carrying out the scoring would arrive at slightly different numbers – hence the use of multiple score permutations and Monte Carlo throughout the analysis to mitigate this issue. Even with these tools, however, the initial scoring is massively influential, which is clearest in my scoring of the Economic Effects criterion.

As a result, some analysts may find that the Economic Effects score is too low (for instance, they may want to include externalities from increased commerce at Lynetteholmen). To address such potential criticism, I have rerun the analyses with an inflated Economic Effects score of 4 (adding +3) which puts it equal to the second lowest scored criterion, Health & Wellbeing. This section reruns the analysis with the inflated scores.

4.4.1 Unweighted Analysis

As in the original analysis, with equal weighting, the base scenario outperforms Lynetteholmen by a sizeable margin (Table 10). With the criteria weighted equally, no intervention is assessed as favorable to enacting the Lynetteholmen project.

8 Inflated - Equal Weights

	Assigned	ln(Assigned)	Proportional	ln(Proportional)
Score	-1.625	-0.201	-0.341	-0.142
Top Contributor	Environmental Effects (21.6%)	Environmental Effects (15.9%)	Conservation (22.8%)	Conservation (19.1%)
Bottom Contributor	Economic Effects (7.8%)	Economic Effects (10.3%)	Economic Effects (5.8%)	Economic Effects (7.3%)
Monte Carlo 20 %	0 %	3.8 %	0 %	0.1 %
Monte Carlo 50 %	4.6 %	24.7 %	3.6 %	11.6 %
Positive Weights	Economic Effects = 0.125	Traffic = 0.125	Soil Deposit = 0.125	Storm Surge = 0.125
Negative Weights	Conservation = 0.125	Environmental Effects = 0.125	Health and Wellbeing = 0.125	Resource Use = 0.125

Table 10: Unweighted analysis with 8 criteria and inflated Economic Effects. The base scenario outperforms Lynetteholmen regardless of score transformation, with Economic Effects contributing least to the result.

4.4.2 Policy Rationales

However, for both the Human Biased Rationale (Table 11) and the Economic + Climate Rationale (Table 12), the new score results in Lynetteholmen being favored in some 8-criteria permutations at 300 % overweighting. At 500 % overweighting (Table 13), the inflated Economic Effects score gives a stronger positive result for Lynetteholmen, though some permutations still have only moderate Monte Carlo scores.

8 Inflated - Human Centered Rationale 300 PCT.

	Assigned	ln(Assigned)	Proportional	ln(Proportional)
Score	-0.214	0.141	-0.066	0.009
Top Contributor	Traffic (19.5%)	Traffic (21%)	Traffic (20.9%)	Traffic (21.8%)
Bottom Contributor	Soil Deposit (6.5%)	Soil Deposit (7%)	Soil Deposit (7%)	Soil Deposit (7.3%)
Monte Carlo 20 %	26.4 %	88.6 %	15 %	57.9 %
Monte Carlo 50 %	39.6 %	68 %	33.7 %	52.4 %
Positive Weights	Economic Effects = 0.214	Traffic = 0.214	Soil Deposit = 0.071	Storm Surge = 0.071
Negative Weights	Conservation = 0.071	Environmental Effects = 0.071	Health and Wellbeing = 0.214	Resource Use = 0.071

Table 11: Human Biased Rationale overweighted 300 % with 8 criteria and inflated Economic Effects. Results are mixed, with weak Monte Carlo probabilities.

8 Inflated - Economic + Climate Rationale 300 PCT.

	Assigned	ln(Assigned)	Proportional	ln(Proportional)
Score	-0.062	0.273	-0.099	0.02
Top Contributor	Resource Use (25.3%)	Resource Use (21.7%)	Resource Use (31.6%)	Resource Use (27.4%)
Bottom Contributor	Health and Wellbeing (4.2%)	Health and Wellbeing (5.3%)	Health and Wellbeing (3.5%)	Health and Wellbeing (4.2%)
Monte Carlo 20 %	44.1 %	98.8 %	11.5 %	65.4 %
Monte Carlo 50 %	47.7 %	80.6 %	33.4 %	57 %
Positive Weights	Economic Effects = 0.188	Traffic = 0.188	Soil Deposit = 0.062	Storm Surge = 0.188
Negative Weights	Conservation = 0.062	Environmental Effects = 0.062	Health and Wellbeing = 0.062	Resource Use = 0.188

Table 12: Economic + Climate Rationale overweighted 300 % with 8 criteria and inflated Economic Effects. Results are mixed, with weak to moderate Monte Carlo probabilities.

8 Inflated - Human Centered Rationale 500 PCT.

	Assigned	ln(Assigned)	Proportional	ln(Proportional)
Score	0.35	0.278	0.044	0.069
Top Contributor	Traffic (24.3%)	Traffic (25.1%)	Traffic (26.6%)	Traffic (27%)
Bottom Contributor	Soil Deposit (4.9%)	Soil Deposit (5%)	Soil Deposit (5.3%)	Soil Deposit (5.4%)
Monte Carlo 20 %	84.8 %	98.9 %	75.3 %	94.7 %
Monte Carlo 50 %	65 %	80.7 %	60 %	72.9 %
Positive Weights	Economic Effects = 0.250	Traffic = 0.250	Soil Deposit = 0.050	Storm Surge = 0.050
Negative Weights	Conservation = 0.050	Environmental Effects = 0.050	Health and Wellbeing = 0.250	Resource Use = 0.050

Table 13: Human Biased Rationale overweighted 500 % with 8 criteria and inflated Economic Effects. Lynetteholmen is favored with moderate to strong Monte Carlo probabilities.

Adding +3 to the score of the Economic Effects criterion opens the possibility of different and more nuanced policy rationales to result in a Lynetteholmen recommendation, but still requires a heavy overweighting of the economy-centered criteria. In the Human Centered Rationale model, Traffic contributes 24.3-27 % to the result, more than double that of the highest contribution from an unweighted criterion (Figure 8).

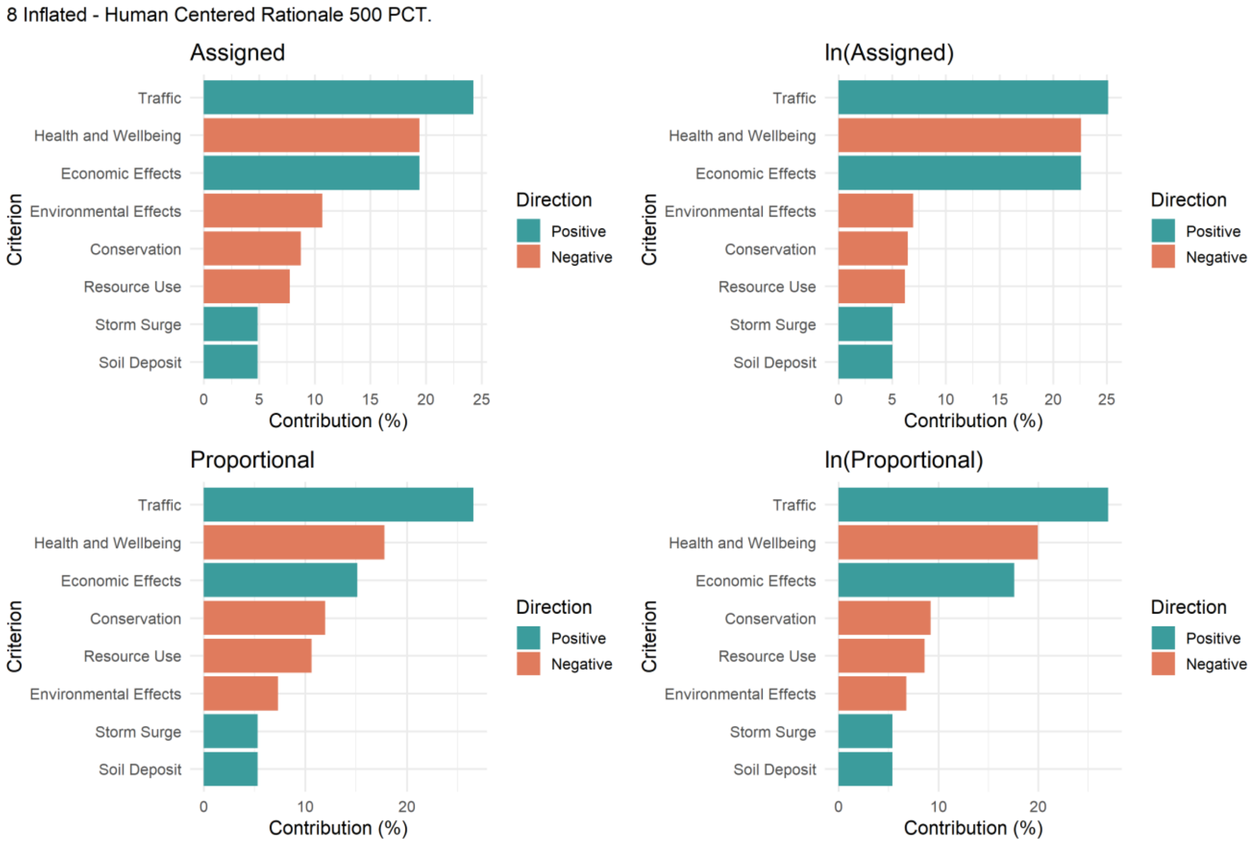

Figure 8: Tornado Plot with Economic Rationale overweighted by 500 % with 8 criteria. Unweighted criteria contribute approximately 5-10 % to the results.

For the 6-criteria permutations, neither rationale favors Lynetteholmen at 300 % (Table 14). Given that the 6-criteria permutations include fewer positive criteria for Lynetteholmen, this result is unsurprising, although it again reinforces the importance of the choice of model, criteria inclusion, and scoring.

6 Inflated - Economic + Climate Rationale 300 PCT.

	Assigned	ln(Assigned)	Proportional	ln(Proportional)
Score	-0.75	-0.101	-0.128	-0.068
Top Contributor	Traffic (23.8%)	Traffic (24.8%)	Traffic (27.4%)	Traffic (27%)
Bottom Contributor	Health and Wellbeing (6.3%)	Health and Wellbeing (7.5%)	Health and Wellbeing (6.1%)	Health and Wellbeing (6.7%)
Monte Carlo 20 %	2.3 %	22.4 %	2.9 %	7.7 %
Monte Carlo 50 %	21.9 %	38 %	22.9 %	28.3 %
Positive Weights	Economic Effects = 0.250	Traffic = 0.250		
Negative Weights	Conservation = 0.083	Environmental Effects = 0.083	Health and Wellbeing = 0.083	Resource Use = 0.250

Table 14: Economic + Climate Rationale overweighted 300 % with 6 criteria and inflated Economic Effects. The base scenario is favored across permutations, with strong to moderate Monte Carlo probabilities.

4.4.3 Economic Rationale

As one would expect, the purely Economic Rationale is also more favorable to Lynetteholmen when the Economic Effects criterion score is inflated, with 7 permutations favoring Lynetteholmen at 300 % overweighting and all 8 permutations favoring Lynetteholmen at 500 % overweighting (Table 15-18). The Monte Carlo simulation shows that results are more stable in this model than in original analysis, but at 300 % overweighting, there are still 4 permutations where more than 25 % of iterations favor the base scenario. At 500 % overweighting, the results are stable and clear, with all permutations favoring Lynetteholmen in more than 90 % of iterations.

6 Inflated - Economic Rationale 300 PCT.

	Assigned	ln(Assigned)	Proportional	ln(Proportional)
Score	0.1	0.237	0.046	0.056
Top Contributor	Traffic (28.3%)	Traffic (29.8%)	Traffic (33.5%)	Traffic (33%)
Bottom Contributor	Health and Wellbeing (7.5%)	Health and Wellbeing (8.9%)	Health and Wellbeing (7.5%)	Health and Wellbeing (8.1%)
Monte Carlo 20 %	59.6 %	96.3 %	74.5 %	88.2 %
Monte Carlo 50 %	52.5 %	74.6 %	58.5 %	66.4 %
Positive Weights	Economic Effects = 0.300	Traffic = 0.300		
Negative Weights	Conservation = 0.100	Environmental Effects = 0.100	Health and Wellbeing = 0.100	Resource Use = 0.100

Table 15: Economic Rationale overweighted 300 % with 6 criteria and inflated Economic Effects. Lynetteholmen is favored or even, but with generally weak Monte Carlo probabilities.

8 Inflated - Economic Rationale 300 PCT.

	Assigned	ln(Assigned)	Proportional	ln(Proportional)
Score	0.417	0.432	0.034	0.095
Top Contributor	Traffic (21.7%)	Traffic (24%)	Traffic (23.1%)	Traffic (24.5%)
Bottom Contributor	Health and Wellbeing (5.8%)	Health and Wellbeing (7.2%)	Health and Wellbeing (5.1%)	Health and Wellbeing (6%)
Monte Carlo 20 %	87.4 %	100 %	68.9 %	98.6 %
Monte Carlo 50 %	66.9 %	92.9 %	57.5 %	79.6 %
Positive Weights	Economic Effects = 0.250	Traffic = 0.250	Soil Deposit = 0.083	Storm Surge = 0.083
Negative Weights	Conservation = 0.083	Environmental Effects = 0.083	Health and Wellbeing = 0.083	Resource Use = 0.083

Table 16: Economic Rationale overweighted 300 % with 8 criteria and inflated Economic Effects. Lynetteholmen is favored or even, but with moderate or weak Monte Carlo probabilities in several permutations.

6 Inflated - Economic Rationale 500 PCT.

	Assigned	ln(Assigned)	Proportional	ln(Proportional)
Score	1.357	0.655	0.257	0.203
Top Contributor	Traffic (35.2%)	Traffic (36%)	Traffic (41.3%)	Traffic (40.3%)
Bottom Contributor	Health and Wellbeing (5.6%)	Health and Wellbeing (6.5%)	Health and Wellbeing (5.5%)	Health and Wellbeing (6%)
Monte Carlo 20 %	100 %	100 %	100 %	100 %
Monte Carlo 50 %	91.2 %	97.6 %	93.4 %	95.8 %
Positive Weights	Economic Effects = 0.357	Traffic = 0.357		
Negative Weights	Conservation = 0.071	Environmental Effects = 0.071	Health and Wellbeing = 0.071	Resource Use = 0.071

Table 17: Economic Rationale overweighted 500 % with 6 criteria and inflated Economic Effects. Lynetteholmen is clearly favored with strong Monte Carlo probabilities.

8 Inflated - Economic Rationale 500 PCT.

	Assigned	ln(Assigned)	Proportional	ln(Proportional)
Score	1.438	0.749	0.222	0.214
Top Contributor	Traffic (28.7%)	Traffic (30.7%)	Traffic (31%)	Traffic (32.1%)
Bottom Contributor	Health and Wellbeing (4.6%)	Health and Wellbeing (5.5%)	Health and Wellbeing (4.1%)	Health and Wellbeing (4.7%)
Monte Carlo 20 %	100 %	100 %	100 %	100 %
Monte Carlo 50 %	94.3 %	99.6 %	90.3 %	97.4 %
Positive Weights	Economic Effects = 0.312	Traffic = 0.312	Soil Deposit = 0.062	Storm Surge = 0.062
Negative Weights	Conservation = 0.062	Environmental Effects = 0.062	Health and Wellbeing = 0.062	Resource Use = 0.062

Table 18: Economic Rationale overweighted 500 % with 8 criteria and inflated Economic Effects. Lynetteholmen is clearly favored with strong Monte Carlo probabilities.

With the Economic Effects score inflated, the Economic Rationale with 500 % overweight is the first model which is unequivocally in favor of Lynetteholmen. Even under significant uncertainty, this model gives a clear recommendation to Lynetteholmen. If these scores and weights were accurate (or arrived at through a rigorous elicitation process), the policy recommendation would be clear. This again warrants a closer inspection of the criteria contributions which govern this result. Figures 9 and 10 show the contributions from each criterion to arrive at this stable result.

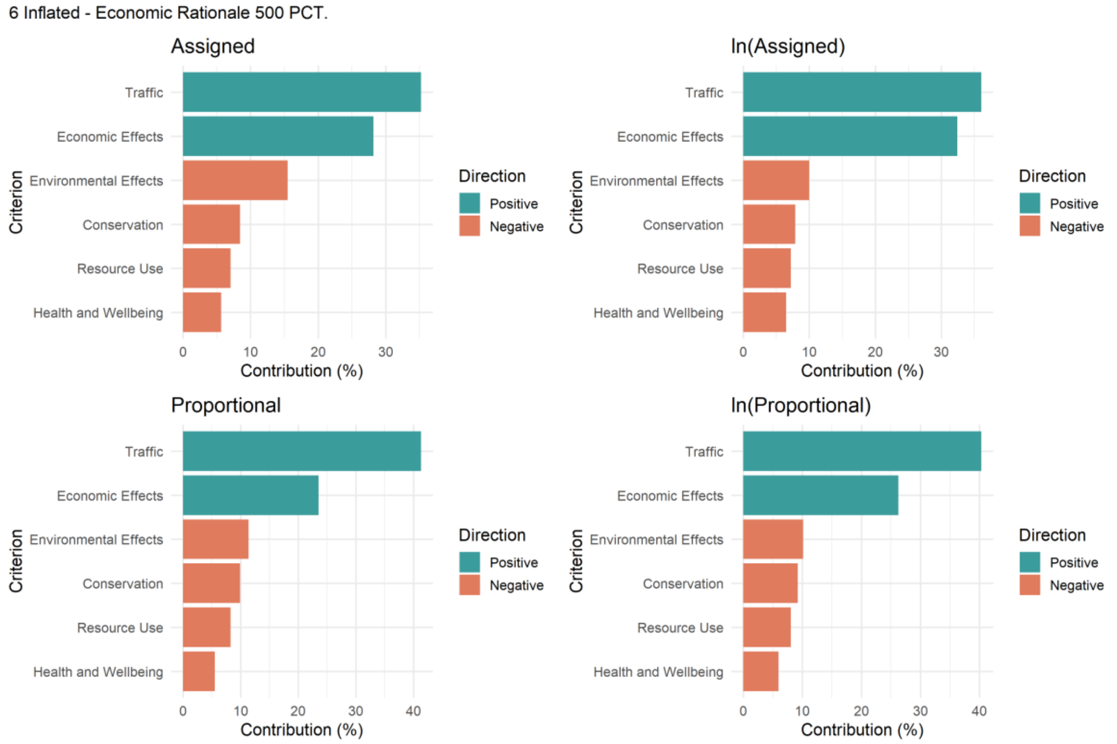

Figure 9: Tornado Plot of Economic Rationale with 6 criteria and inflated Economic Effects. Traffic contributes more than 35 % and the unweighted criteria contribute ≈ 15 % or less.

Figure 10: Tornado Plot of Economic Rationale with 8 criteria and inflated Economic Effects. Traffic contributes ≈ 30 % and the unweighted criteria contribute 15 % or less.

Inflating Economic Effects reduces the contribution of Traffic by about 10 percentage points, predictably redistributing this portion of contribution to Economic Effects. If the inflated scoring of Economic Effects is accurate, then the Economic Rationale weighting scheme could possibly be an accurate representation to decision-maker preferences, and Lynetteholmen could be reasonably recommended.

Using MCDA in this way clarifies the implicit emphasis placed on the different criteria (and the impacts contained in the criteria), showing here the low importance placed on Conservation, Resource Use, Environmental Effects, and Health and Wellbeing, which is necessary to arrive at the Lynetteholmen recommendation. As such, it allows decision-makers to consider whether these prioritizations align with their values and goals.

4.5 Summary

The analysis has tested a series of different weighting schemes against the scores, finding which weights result in a recommendation of enacting Lynetteholmen over the base scenario of no intervention.

In the original scoring, Lynetteholmen could only be recommended in the Economic Policy Rationale weighting scheme. When inflating the Economic Effects criterion, other weighting schemes resulted in a Lynetteholmen recommendation, but with high degrees of uncertainty.

Overall, the analysis has shown that enacting the Lynetteholmen project can be recommended only if we value Traffic gains as more than 30 % of the total gains and losses from the project.

In the following section, I will discuss my results and the efficacy of my approach, considering whether the MCDA is realistic, what it contributes, and how analysts can use the approach in future impact analysis and decision-aiding work.

5. Discussion

The purpose of this thesis has been to examine whether and how a simplified MCDA can strengthen policy impact assessments, utilizing and combining existing impact assessments in a single framework. In the previous section, I carried out an example analysis of the Lynetteholmen case, predominately focused on sensitivity and testing various parameters. In this section, I broaden my perspective and consider the impact of some of the specific choices I have made in my approach, as well as the efficacy of using MCDA in this capacity.

I discuss my scoring, which permutations proved useful, and the stylized weighting schemes I employ, giving concrete recommendations for possible implementation in decision-making processes and tying these considerations into the broader discussion of MCDA versus CBA.

5.1 Can we believe the scores?

In my analysis, the most significant weakness lies in the scoring. Although the scores are intended to accurately combine and translate the conclusions of the EIA, SEA, and CBA, it is highly likely that the authors of those reports would disagree with the specific scores I have assigned.

My analysis shows that changes in the scores used are very impactful, as evidenced by the many models in which different score permutations resulted in completely different results. Any MCDA analysis which lacks a rigorous and transparent scoring procedure is easy to criticize and ultimately disregard, leading to a serious issue for simplified MCDA in public policy.

A typical MCDA process employs field-specific experts to assess each criterion and give their scores. This approach results in valid scores but also adds time and complexity to already extensive processes of impact assessment. This could be remedied by integrating scoring with the existing impact assessment processes.

One possible solution is to have analysts report their EIA and SEA results in a unified framework that allows for an easier translation to MCDA. This solution integrates the expense of eliciting expert evaluations into existing processes, while creating greater comparability between the reports (even if MCDA is not employed).

When combining CBAs in MCDA analyses, one existing practice is to translate the CBA to one or multiple criteria and score it. Keeping the CBA criteria separate from other criteria (such as those from the EIA and SEA) simplifies scoring but also risks obfuscating nuances contained in the CBA. In the Lynetteholmen case, the overall conclusion of the CBA was a DKK 15.1 billion surplus to the entire Lynetteholmen project. Contained herein, however, is the valuation of *brugereffekter* (predominately a reduction of time spent in traffic), which amounts to DKK 18.3 billion (Transportministeriet, 2022a, p.19). Combining the CBA into a single criterion would obfuscate this valuation and thus reduce the potential for the MCDA to aid decision-makers in value-based decisions.

As such, the usefulness of MCDA as an alternative or addition to CBA would rely on the CBA results being disaggregated and added to the MCDA analysis as part of several criteria, similar to my approach. This process also avoids the risk of double counting, as some impacts assessed in the MCDA are also assessed in the EIA and SEA.

Finally, some analysts suggest keeping costs entirely separately from MCDA, focusing only on benefits and considering costs only in the second round of evaluation. This approach is methodologically sound, but in my estimation severely underestimates the importance of cost-effectiveness in public policy and would sideline MCDA as merely a component of existing CBA processes.

While the scoring of MCDA is always contestable and would also be so in the case of a rigorous integration in existing policy processes, it is not necessarily more contestable than the valuations carried out as part of current CBA-based evaluations. Furthermore, the MCDA framework has the distinct advantage of transparency in the scoring process, equipping decision-makers and stakeholders to question the scoring decisions regardless of their (lacking) technical expertise.

5.2 Which permutation should we use?

In the analysis section, I have examined eight different score permutations. Comparing the results across permutations is useful as a sensitivity tool, but also adds considerable complexity to interpretation, and would be an unnecessarily cumbersome approach to a practical analysis. Rather, a single score permutation should be chosen.

5.2.1 Criteria Inclusions

For the criteria choices, neither the 6-criteria permutations nor the 8-criteria permutations are particularly convincing. I find the 6-criteria model to be biased against Lynetteholmen, since Storm Surge Protection and Soil Deposits are central benefits of the Lynetteholmen project which would need other solutions if Lynetteholmen was abandoned. The 8-criteria model, however, values the Lynetteholmen-solution to these problems very highly (in the range of DKK 18 billion each, considering the valuation of the Traffic criterion which is scored identically). By including both a model which is biased against and a model which is biased in favor of Lynetteholmen, I find those conclusions that are consistent across models to be strengthened. With that said, a valid MCDA model should include measurements for all important criteria, and it is surprising that none of the existing impact assessments attempt to calculate the importance of Storm Surge Protection and Soil Depositing more thoroughly.

While the MCDA framework cannot remedy the lacking data on these criteria in a satisfying way, the process of choosing which criteria to include in the model (which should always be case-specific) drew attention to this lack more clearly than the other impact assessment reports. It is not clear in the EIA, SEA, or CBA what is *not* being considered, whereas the MCDA purports to be a complete decision-making framework, and thereby forces the analyst to consider whether the criteria set is exhaustive.

5.2.2 Score Transformations

In addition to the criteria, there are some issues with several of the score transformations.

The *Assigned* score has the obvious shortcoming that criteria with more included impacts will automatically have inflated scores compared to those with fewer impacts. In my analysis, the Environmental Effects criterion has 8 included impacts and thus receives the highest score of any criterion, despite a lower per-impact score than Conservation or Resource Use (captured in the *Proportional* scoring).

On the other hand, the score of Economic Effects is sharply reduced in the *Proportional* permutations, since it contains both positive and negative impacts unlike for instance Resource Use which contains only negative impacts.

If there is very low confidence in the accuracy of the assigned scores, the logarithmic transformations are helpful since they reduce the influence of higher scores. However, as seen throughout the analysis, the ln-transformations perhaps increase the influence of low scores too significantly. Overall, the *ln(Assigned)* permutation is useful as a comparison, but values Economic Effects too highly to be the primary permutation underlying conclusions.

5.2.3 Rigorous Scoring

Properly institutionalizing MCDA would require a unified scoring system where each criterion is scored on a given range, rather than the impacts being scored individually and then combined, as in my approach. Only by creating a rigorous scoring regime that integrates MCDA scoring directly in the other impact assessment reports, would the scores be reliable enough to provide a strong support to decision-making processes.

With that said, I find the *Proportional* scoring permutations to yield the most believable scores among the options used here. In addition, utilizing multiple scoring permutations for comparison as I have done here is useful to check the stability of the scores, but increases the cognitive constraints of interpreting results and is unlikely to be useful in policy-processes.

5.3 Are the weightings realistic?

In the Policy Rationales section of the analysis, I have employed quite stylized weighting schemes, as opposed to attempting to create more realistic weightings with each criterion having a unique weight rather than simply an overweighted and an underweighted category. This stylization allows for quick, clear, and simple experimentation. Furthermore, any weightings chosen by me will unavoidably have a degree of arbitrariness, which attempting realistic weightings only serves to obfuscate.

Having also experimented with more complex weighting schemes, these do not change my findings regarding the Lynetteholmen case. Even with a more nuanced or mixed weighting scheme, the overall contributions would have to be quite similar: For Lynetteholmen to be recommended, Traffic must be overweighted by 400-500 %, and Environmental Effects, Conservation, and Resource Use must be underweighted proportionally.

While a properly elicited (and thus more accurate and nuanced) weighting scheme is preferable, utilizing stylized weights in this manner still yields a useful and communicative result.

Interestingly, it is possible to compare this result to the CBA, in which *brugereffekter* makes up approximately 22 % of calculated gains and losses ([Author's calculations based on] Transportministeriet, 2022a, p.19). This is lower than the necessary 30 % contribution of Traffic to the MCDA analysis for Lynetteholmen to be recommended, but shows the importance of the Traffic criterion to the CBA results as well. Given the high number of negative environmental effects which are not included in the CBA, the higher percentage contribution of Traffic necessary for the MCDA to recommend Lynetteholmen is unsurprising.

5.4 How useful is this method?

The questions I've asked above are important considerations. If simplified MCDA is to be implemented as a supplement or alternative for CBA as decision-making aid, then methodological choices regarding scoring, weighting, utilizing existing data, and creating realistic inputs without the need for a full participatory process need to be explored and settled. If we assume that those questions can be answered satisfactorily, we must then answer a more fundamental question of the usefulness of MCDA.

It is my assertion that the MCDA literature is too narrowly caught up in becoming increasingly accurate, rather than becoming useful. CBA is the dominant decision-making aid for public policy not because it is accurate, but because it is easy to understand, relatively cheap, and consistent. Perhaps the most poignant criticism of the CBA approach can be summarized as: *CBA measures whether a solution is efficient, not whether it is effective*. MCDA is built to measure and consider effectiveness, and to do so in a context-specific and nuanced manner. However, without some short handing, some heuristics – along the lines of the accepted valuation techniques and value transfer databases of the CBA approach – MCDA becomes so *inefficient* that it simply will not be used in most cases.

Some researchers argue that MCDA is a useful addition only in those cases where the impacts of a project cannot be monetized. From this point of view, as CBA practitioners expand their mathematical techniques and scope, MCDA would become gradually irrelevant. However, this line of thinking misses the central fact that even if CBA is accurately calculating the value of each impact (a dubious assumption), it is still basing this valuation on the aggregated preference of value accruing to individuals, neglecting questions of distribution and disallowing political vision and prioritization from influencing the results.

If the goal is to create an objective framework for impact assessment, then MCDA will always be outclassed by CBA on clarity and consistency. MCDA's usefulness is contingent on the contention that objectivity is not an attainable goal; that striving towards it merely obscures which subjective judgements wind up governing results.

At the same time, however, using MCDA presupposes that data-driven impact assessments do play a meaningful role despite not being objective – that decision-makers should have *some* information framework to guide their hands.

The usefulness of MCDA in public planning and impact assessment thus exists between these extremes: An objective framework for impact assessment is unattainable and misleading, yet discarding the notion of information-based decision-making would be a mistake. As my analysis has shown, scoring the alternatives in MCDA is a complicated and contested process, which is as prone to bias and misuse as any other impact assessment approach. There is no tradeoff between effectiveness, efficiency and transparency which completely avoids the pitfalls of inaccurate scoring completely. While far from perfect, MCDA offers a middle ground for these standpoints, which is better balanced than the current status quo.

My rudimentary exercise in this thesis has showcased the potential of MCDA for better utilizing the results of non-monetary impact assessments, making transparent those assumptions which CBA obscures. Even using a flawed set of scores and arbitrary weighting schemes, it has been possible to uncover and articulate the implicit priorities underlying the Lynetteholmen project, thereby creating an alternative to the equally simplistic conclusion of the CBA.

For MCDA to be useful in practical public policy decision-making, however, researchers must create an adjustable framework which can be quickly and efficiently applied to a multitude of cases, and which can be expanded or contracted as necessary for different scenarios. Striking a balance between efficiency and accuracy is paramount for MCDA to become a viable addition and/or alternative to CBA in more cases.

6. Conclusion

This thesis has examined the potential for simplified MCDA to be used as a unifying impact assessment framework, allowing otherwise incomparable impacts to be weighed against one another, thus equipping decision-makers to consider whether a given solution is compatible with their preferences. I have asked the question:

> *How can a simplified Multi-Criteria Decision Analysis be used to support ex-ante impact assessment within public policy processes?*

To construct and test a simplified MCDA framework, I have looked at the Lynetteholmen case, translating existing impact assessment reports into a unified set of scores, combining those scores with different weighting schemes, and conducted a series of sensitivity tests.

In the context of a largescale public infrastructure project, I find that simplified MCDA has a strong potential to increase the transparency and clarity of ex-ante impact assessments. Using simplified MCDA in this capacity can help inform non-expert decision-makers on the underlying assumptions in the recommendations given, thus enabling them to make decisions in line with their preferences and vision.

Despite MCDA being developed to choose between multiple alternatives, a simplified approach utilizing only one alternative against a base scenario, thus streamlining it with existing CBA and impact assessment practices, still resulted in additional insights about the project's efficacy.

However, I have also found that scoring impacts based on existing impact assessment reports in a rigorous and reliable way is challenging. The construction and scoring of each criterion underpins (or undermines) the MCDA results, and the lack of a valid scoring stage leads to biased and uncredible results. To maximize the MCDA methods potential in public policy decision-making, impact assessment reporting would have to be streamlined within an MCDA framework, to increase comparability across existing reports.

Furthermore, I find that focusing on sensitivity to uncertainty in inputs provides important nuance to the results and alleviates some issues of imprecision in the scoring stage. Utilizing Monte Carlo probabilities provides a simple and intuitive result, while recognizing the uncertainty inherent in predictions of future impacts.

Simplified MCDA, if implemented rigorously and integrated with other impact assessment frameworks, has the potential to strengthen ex-ante impact assessment processes, without adding substantially to the cost or complexity of existing practices.

It remains uncertain whether a simplified MCDA approach would be equally effective – or equally straightforward to implement – in policy contexts where the routine use of multiple impact assessments is absent. Nevertheless, the potential for increased transparency in making the underlying assumptions of impact assessments explicit represents a meaningful advantage, suggesting that MCDA remains a worthwhile approach to consider.

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