Cost-Benefit Analysis as a Sustainability Assessment Tool: Evidence from Dutch ex-ante motorway appraisal projects

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Abstract

To reach sustainability goals, future motorways need to be built and function sustainably within their environment. Therefore, it is necessary to assess the sustainability impacts of policy options and alternatives in ex-ante motorway appraisal projects. Cost-Benefit Analysis is an economic appraisal tool that is widely used to evaluate alternatives and identify the best solution to a transport problem, such as congestion or safety concerns. Currently, scientific literature does not provide a comprehensive analysis of the extent to which CBA can be used as a sustainability assessment tool in motorway appraisal projects. This study seeks to understand to what extent CBA can be and is being used as a sustainability assessment tool in these projects, in theory, and within Dutch CBA practice. It makes use of a literature study, case study research and an expert survey. A set of six criteria for evaluating sustainability assessment tools was derived from literature and compared to practice. These criteria are (1) boundary orientation, (2) full approach, (3) strategic sustainability thinking, (4) trade-offs, (5) contextual input and (6) transparency. The findings show that CBA can to a large extent be used as a sustainability assessment tool. However, Dutch practices have to be improved to do so.

Preface

These are the final words I am adding to this document. Over the last year, I have devoted my time to answering a research question that deeply concerns me. This master thesis gives insight into how an embedded decision-making tool, Cost-Benefit Analysis, can aid the prioritization of sustainable alternatives in motorway appraisal projects.

After a long preparation phase, I started my thesis work in September of 2022 and over the last nine months I analysed scientific literature, a wide variety of policy documents, conducted interviews and conducted a survey. All this research has been compiled in this document.

I would like to thank my supervisors, Frans, João, and Andreas for their support and feedback over the last year and the preceding preparation phase. I would also like to thank my family and friends for their support during this sometimes-difficult process. In particular, I would like to thank Wido, with whom I spent a lot of time in the library theorizing and discussing and Aline, for supporting me over the last two years and proofreading my thesis.

This concludes my student time at the University of Twente, which I am leaving with a master's degree in Civil Engineering & Management and a master's degree in Public Administration. While I certainly wished the process of obtaining these degrees had been easier, I am grateful and happy to leave the University of Twente and start my professional career. I am looking forward to working on challenging projects and helping solve the problems of the future.

Simon Agterhuis,
May 2023, Enschede

Summary

Worldwide, there is an increasing demand for transport infrastructure. At the same time, the negative effects of current societal practices on the planet and society, have increased the urge to become sustainable. Currently, motorway infrastructure is typically not seen as sustainable. While allowing many people to travel to their destinations every day, most infrastructure has been built using polluting technologies and has negative effects on the environment.

The scientific and policy-making field of ex-ante motorway appraisal is focused on finding the most efficient solutions to current or future transport problems. Policymakers use assessment tools to identify the (package of) solutions, often referred to as an alternative, that will solve the transport problem with acceptable negative consequences. Cost-Benefit Analysis (CBA) is an economic appraisal method rooted in utilitarianism, that has been traditionally used to evaluate the societal costs and benefits of these motorway projects. The costs and benefits are identified, quantitively assessed, converted into monetary value and discounted towards the future to identify the most suitable alternative. Much research has been devoted to the limitations and strengths of CBA, but few studies have specifically evaluated it in relation to the new challenge of sustainability.

Sustainability assessment is a scientific field that aims to evaluate the sustainability impacts of a project, proposal, or policy. Sustainability has been defined many times over the last decades, but a well-accepted and used definition of the Brundtland Commission is that sustainable development 'meets the needs of the present without compromising the ability of future generations to meet their own needs'. It leaves the generations that will come after us with at least the same resources as the previous generation had to fulfil their needs. What these needs are and what should be sustained for future generations is subject to debate. Various understandings of this concept exist, including the Three Pillar Framework, Circles of Sustainability, and the Natural Step Framework. The frequently used Three Pillar Framework identifies three distinct impact categories that should be considered when evaluating sustainability: the economic, environmental, and social dimensions.

Research Problem

The assessment of sustainability is being implemented into engineering and policy-making practices in several ways. The development of new tools and frameworks seeks to help policymakers and engineers evaluate the sustainability impacts of their decisions. These sustainability assessment tools generally do not apply to and are therefore not used in ex-ante motorway appraisal. This research evaluates whether a currently embedded decision-making tool, CBA, in ex-ante motorway appraisal projects can be used for sustainability assessment. While most authors acknowledge that CBA can, at least partially, be used as a sustainability assessment tool, many identify limitations. A thorough, theoretical, and practice-based evaluation has not been found in scientific literature. Therefore, this study answers the following research question:

To what extent can Cost-Benefit Analysis in ex-ante motorway appraisal projects be used as a sustainability assessment tool?

Literature Review

To answer the research question, several sub-questions were created. The first three consider (1) how the CBA methodology is generally used in motorway appraisal, (2) what requirements a tool should meet to be used as a sustainability assessment tool, and (3) how the best practices in CBA relate to these requirements. A literature review was used to answer these questions.

In the Netherlands, the CBA is part of an Exploratory Study, which is a structured policy framework for the identification of a solution to a transport problem. Along with project goal achievement and an environmental impact assessment, the CBA is one of the formal decision-making tools that underpins the final policy decision, the 'Preferred Decision'.

The state-of-the-art of sustainability assessment contains many different definitions and frameworks of sustainability. For ex-ante motorway appraisal specifically, sustainability assessment tools are required to fulfil the following six criteria:

1) Tools must have *boundary orientation* to indicate sustainability performance, by clearly adopting limitations for impacts that are deemed unsustainable.
2) Tools must have a *full approach* towards economic, environmental, and social sustainability impacts, which means they must assess the impacts to the fullest extent and detail possible.
3) Tools must *strategically include sustainability thinking* in their analyses, focused on life cycle thinking and the use of different discount rates for different impacts.
4) Tools must show different *trade-offs* between different types of solutions and indicate uncertainty and risks of the results.
5) Tools must account for *contextual input* and must adjust their implementation based on local input and priorities.
6) Tools must ensure *transparency* about their outcomes and methodology and provide traceable documentation for the choices made.

Comparing international CBA best practices to these criteria shows that CBA can fulfil most of the requirements. Practitioners of CBAs can establish boundary conditions and assess economic and most environmental criteria fully, meaning they can be quantified, monetised, and included in the Cost-Benefit ratio. Although social criteria are largely disregarded in CBAs due to the difficulty of monetization and lack of perceived importance, some methods to assess them in CBA do exist. There are clear examples of CBA including different discount rates and Life Cycle Analysis to implement life cycle thinking. Although it is a technical analysis tool, there are abundant ways to ensure that contextual input is taken into account and trade-offs between alternatives are shown. The same applies to the transparent presentation and explanation of the results and the methodology.

Case Study Research

The theory of CBA is different from the practice of CBA in motorway appraisal projects. Current CBA guidelines allow for a large variety in the assessment methods used, mainly because time and financial resources are limited, for instance by the project size. The second part of the research focuses on identifying to what extent Dutch CBA practice conforms to the requirements for sustainability assessment tools.

Eight Dutch motorway projects from the last 10 years were analysed in a multiple-case study. With CBA reports and other Exploratory Study documentation, the CBA practices were compared to the ideal framework. Additionally, interviews with personnel involved in the projects were used for deliberation, elaboration, and validation of the results. In the end, the findings indicate that the Dutch CBA practice performs largely insufficiently to be used for sustainability assessment. Even though CBA practice is institutionalised and continuously being developed in the Netherlands, many of the recent practices for sustainability assessment have not made their way into CBA practice. The assessment of economic sustainability is, perhaps unsurprisingly, well-established and in most cases approximates the best practices of CBA. Investment costs and direct travel time benefits are estimated well. The underperforming impacts are the reliability benefits and assumed wider economic benefits of motorway projects, mainly due to the assumptions underlying the analyses. Regarding environmental sustainability, the Dutch practices for the

assessment of noise and air pollution are well-established. Additionally, in more recent years, the prices of CO2 emissions have risen. More life cycle assessments have been included. However, other environmental criteria do not explicitly make it into the CBA. Examples of this include ecological effects and landscape degradation. The social criteria make it into the CBA report even less, unless the project goals specifically require it. Although showing the distributive effects of projects is part of the methodology, few examples can be found in practice. Impacts on local communities such as community disruption and the loss of cultural heritage are seldom found in CBA reports.

When looking at the boundary conditions set by the CBA practitioners and the implementation of strategic sustainability thinking, clear improvements are observed in more recent projects. Time and resources were spent to estimate CO2 emissions during the production of materials and the construction process. In another example, community disruption and spatial quality were assessed quantitively and monetized. However, in most projects, the usage and operation life cycle phase still make up the majority of the analysis with little attention to other life cycle phases.

When looking at the presentation of trade-offs, a few projects considered only a low number of alternatives. In all projects, risks and uncertainty in costs and benefits are well-researched and presented. However, the accepted practice of comparing the alternatives to a reference scenario without mentioning the effects of the autonomous developments in that reference scenario is problematic for sustainability assessment. The relative size of the effects compared to the reference scenario cannot be retrieved from this presentation.

Contextual input and transparency are limitedly embedded in Dutch CBA practices. Input for the CBA comes from clients and powerful stakeholders. Input from the public is generally not considered. Local interests are covered by including local governments in the Exploratory Study. Participatory processes during the Exploratory Study are focused on other policy-making issues than the CBA methodology and results. As experienced in this research, it is difficult to find published CBA reports and, in many cases, it is unclear to what extent the outcomes of the CBAs influenced the final Preferred Decision. Despite the technical nature of the CBA methodology, more explanation of results and methodology is necessary.

Expert Survey

The case study research resulted in 29 potential improvements, based on the comparison of current practices to the best practices from the ideal framework. To validate the findings and to identify the most feasible improvements, a survey was distributed to 30 experts that are involved with CBA in Exploratory Studies. 14 responses were provided by employees from the government, consultancy firms and policy analysis organizations. The respondents were asked to indicate their level of agreement with each improvement and to explain their opinion if they did not (fully) agree. Secondly, they were asked to identify the most feasible out of the 29 improvements.

Eleven improvements were marked as feasible. These improvements are supported by CBA experts and are easy to implement. For instance, end-of-life valuation and replacement of physical infrastructure should be part of the infrastructure costs. Safety effects, noise and air pollution should be assessed using the detailed studies for the Environmental Impact Assessment (EIA) as a basis, and only use a vehicle-kilometre-based approach for the larger study area. CO2 emissions should be calculated for as many lifecycle phases as possible and valued with an efficient CO2 price per tonne while adjusting for Emission Trading System (ETS) prices, already incorporated in market prices. A description of the division of costs and benefits across different stakeholder groups, as well as a list of considered local interests, should be provided. Clients should publish the CBA results in the final policy document and explain how it influenced the policy decision. CBA practitioners should be present at public information meetings to explain the results and methodology. A central website should be created where CBA reports are published, to improve learning

for the CBA community and provide easy transparent access for interested citizens. Another feasible improvement is for clients and CBA practitioners to consistently consider a wide variety of different alternatives, with the help of a quick-scan CBA in the early phases of the Exploratory Study. Furthermore, Dutch policy analysis organisations should create a guideline for a core set of effects that have to be considered in motorway appraisal projects.

The other eighteen suggested improvements require additional research to improve their practical feasibility. Policy analysis organisations and calculation number firms (NL: kengetal onderzoekers) should determine the most practically feasible and impactful improvements. They should develop clear frameworks, guidelines, and tools to implement them. This includes a framework or guideline for attributing wider economic benefits. The same goes for some environmental and social impacts, such as the negative effects of the construction process on residents, the external effects of energy usage and material extraction and production, and the effects on nature areas, both recreational and ecological. Other impacts to be considered include the valuation of landscape degradation, cultural heritage, community disruption, and labour conditions in the production process of scarce construction materials. Policy analysis organisations should evaluate the used discount rates from a sustainability perspective and create structured tools to estimate the external effects over all life cycle phases of infrastructure objects. Regarding contextual input, the added value of including local input for CBAs should be evaluated, especially as a method for deliberation and explanation. For the readability of reports, the positioning of the calculation numbers within the CBA report should be evaluated. Additional research into showing trade-offs is necessary to determine how CBA practitioners can accurately show all effects caused by the expected autonomous developments. This is important because it would indicate the relative impact of the project alternatives and show which problems the project addresses. A comparison of Dutch calculation numbers to international standards, such as the World Health Organisation (WHO) norms, with specific attention to the benefits of assessing impacts with a QALY or a DALY-based approach, would be worthwhile.

Limitations

One of the limitations of this study is related to the limited scope of the literature review on sustainability assessment and its application in the creation of the ideal framework for best practices. Other limitations concern the generalisability of the findings in the case studies and the expert survey, due to the limited sample sizes. Future research is needed to specifically analyse the CBA practices in other countries, to generalise the findings of this study. Additionally, while some attention was paid to practical feasibility, the actual influence of proposed improvements on policy decisions was not evaluated. The results of this study cannot be used to explain the substantial difference between the theory of sustainability assessment and the current state of Dutch CBA practice.

Conclusion

The findings of this research give nuance to the widely replicated notion that CBA cannot be used as a sustainability assessment tool. CBA can be used as a form of sustainability assessment, provided that the right techniques, methods, and resources are put into place. This study indicates that CBA is a structural part of the decision-making process in ex-ante motorway appraisal projects. In theory, it can be used for sustainability assessment to a large extent, but in Dutch practice, substantial improvements must be made to facilitate this. Dutch CBA practice has not been developed with sustainability assessment at its core, but this study suggests that with more research and the continuous development of the methodology, Dutch CBA practices can be improved.

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1. Introduction

Global population growth, urbanization, technological developments, and an increased desire for maintaining a comfortable and modern life have stimulated the demand for new physical infrastructure (Kardes, Ozturk, Cavusgil & Cavusgil, 2013). However, the current motorway infrastructure is not sustainable. Our motorways have been built using polluting technologies and inefficient resource management. They have negative effects on our environment (Health Effects Institute, 2010; Brugge & Durant., 2007; Newman et al., 2012). Currently, several countries make use of Cost-Benefit Analysis (CBA) for the ex-ante appraisal of motorway projects to determine the most efficient alternative to solve a transport problem. In appraisal projects, an alternative is a package of solutions or measures, such as widening the road with extra lanes, changing the design of junctions, or rerouting the entire road.

Over the last decades, several tools to assess the sustainability of project proposals have been developed to enable the comparison and prioritization of sustainable alternatives (Bueno, Vassallo & Cheung., 2015). These include rating systems, (the adaption of) traditional decision-making tools, evaluation frameworks, and checklists (Bueno et al., 2015). They aim to provide a complete and accurate representation of the sustainability impacts of a construction project. However, they differ in 'what' they assess, the definition of sustainability used, and 'how' they assess it (Bond, Morrison-Saunders & Pope 2012). Commonly, sustainable development is understood as a development that 'meets the needs of the present without compromising the ability of future generations to meet their own needs.' (World Commission on Environment and Development, 1987, p.16). Sustainability is a safe operating space, which leaves the next generations with at least as much as the current generation has received from the previous generation (Cornet, Barradale, Barfod & Hickman, 2017). Sustainability Assessment is consequently described as any process that directs decision-making towards sustainability (Pope et al., 2017).

Unfortunately, policy decision-making for motorway projects often has a rigid multi-actor and political complexity, that obstructs the implementation of sustainability assessment tools into the policy-making process (OECD, 2018). CBA has a unique position, as it is traditionally already used to appraise project alternatives. It can also be used as an economic approach to sustainability assessment (OECD, 2018). This creates a unique opportunity to integrate the assessment of sustainability impacts into an existing policy-making framework for motorway appraisal.

1.1 Transport Appraisal

Transport infrastructure aims to improve the accessibility for people, companies, and activities; to make it easier to travel from point A to B. On the other hand, this transport infrastructure comes with a variety of costs, both directly and indirectly, monetary and non-monetary. While motorways enable and empower citizens to travel to and from their activities quickly and comfortably, their usage causes nuisance for stakeholders, including flora and fauna. Motorways take up space that cannot be used for other spatial functions. Given these trade-offs, transport appraisal aims to find an effective and efficient solution to transport problems, such as alleviating congestion, improving safety, or reducing travel distance. The chosen alternative should not cause disproportionate negative externalities on its environment. In other words, the appraisal goals must be reached at an acceptable financial cost and with a proportionate (negative) impact on stakeholders. To ensure the choice of a cost-effective solution and to legitimately balance the various stakeholder interests, transport planning makes use of policy frameworks. These policy frameworks provide a set of analytical and political steps, through which the most suitable solutions are conceptualized and evaluated. To increase the legitimacy of the policy process, participatory processes are used to implement the requirements and wishes of stakeholders, who seldom are granted decision-making

power. The process of stakeholder involvement is usually not transparent, and they can often only guess to what *extent* their input is reflected in the policy decision. The policy-making process is always limited by which ideas, concepts and concerns have been included. The identification of the problem, formulation of alternatives and appraisal of those alternatives is a well-accepted and implemented method of transport planning. Cost-Benefit Analysis is a well-established part of the appraisal phase, and it is used on an operational level to determine the best alternative to a transport problem.

1.2 Sustainability and its assessment

The construction of motorways and the associated industry has a wide variety of environmental and social impacts (Illahi & Shafi Mir, 2020). The transport sector has grown its worldwide emissions by 30 per cent since 1990 and is the only sector to not have reduced its emissions (Nocera & Cavallaro, 2020). Transportation systems influence every pillar of sustainability (Illahi & Shafi Mir, 2020) and sustainable design of motorways can help reach climate goals. This goes for both the operational level of road usage and construction (Rooshdi, Ab Rahman, Majid, Ismail. 2014) and for the strategic level in which the larger transportation system is designed (Abu-Eisheh, Kuckshinrichs & Dwaikat. 2020).

In (inter)national policy contexts, governments have committed to a transformation of the construction industry. In the Netherlands, the construction industry is supposed to reduce its emissions by 55 per cent by 2030. By 2050, all operations must be carbon-neutral and circular (Rijksoverheid, 2022). The transition requires a change across the entire process of designing and constructing motorways. It does not just concern the physical construction itself, but also the planning and decision-making surrounding motorway projects. Sustainability needs to be the main component in the policy-making processes of what to build, where, and when.

Transitioning to sustainability, especially in transportation, is difficult: it is hard to cover every aspect of sustainability, and it is a barrier for communication between the heterogenous pool of stakeholders (Illahi & Shafi Mir. 2020). The inclusion of sustainability into decision-making processes introduces more complexity. Especially in stakeholder-influenced situations, the knowledge of what sustainability encompasses, what role it should play in the appraisal, and how it should be measured is uncertain (Dijk et al., 2017; Potting, Thomas & Gröndahl, 2022). This obstructs an appraisal of project alternatives, that is based on accurate analysis and supported by the involved stakeholders.

The definition of sustainability has changed over the last decades. In the field of sustainability science, theoretical frameworks provide the basis for sustainability assessment by defining broad boundaries for what is considered sustainable and what is not. Early frameworks were based on balancing overpopulation with the biosphere (e.g. the Club of Rome and the UNCHE 1972.). The term ‘sustainable development’ used today was coined in the Brundtland Report, in the late 1980s. After this definition, new frameworks such as the Natural Step and the Triple Bottom Line introduced new ways of thinking about the ‘needs’ of present and future generations (Tuazon, Corder, & McLellan, 2013). An important difference between the frameworks is whether they assess sustainability in an absolute or relative way. Another difference is the way they deal with trade-offs (Vassallo & Bueno, 2021; Gasparatos & Scolobig, 2012). From the so-called weak sustainability perspective, trade-offs between different categories of ‘needs’ are allowed. From a strong sustainability perspective, no trade-offs are allowed (Vassallo & Bueno, 2021). The theoretical frameworks form the basis for tools that assess sustainability impacts. Popular methodologies include Life Cycle Assessment and Environmental Impact Assessment. Sets of metrics and indicators have been developed to form the building blocks for various methodologies (Tuazon et al., 2013). The field of sustainability assessment aims to evaluate the extent to which objects, projects and systems are sustainable, either throughout their life cycle or for specific phases. The assessment is conducted by evaluating the

impacts of different alternatives on sustainability indicators. While interest in sustainability assessment for decision-making is growing (Hoogmartens, van Passel, van Acker & Dubois, 2014), the diversity and continuous development of the field of sustainability assessment make it hard for policymakers, engineers, and stakeholders to derive a common understanding of what sustainability is and what role it should play in the appraisal for motorway projects.

One definition of sustainable projects in transport appraisal is those projects that fulfil the economic development and transportation needs of society with consideration for natural laws and human values (Bueno et al., 2015). Investment in public infrastructure should be justified by social contribution in the short and long term (Sierra, Yepes, Garcia-Segura & Pellicer. 2018; Corner et al., 2018). Possible benefits of mobility projects include an increase in accessibility and mobility, safety improvements and the promotion of healthy modes of transport (Browne & Ryan, 2011). The opportunities to incorporate sustainability in a motorway project decrease as its life cycle progresses (Bueno et al., 2015). A great reduction in negative sustainability impacts can be achieved in the early phases of planning. However, there is currently no standard process for appraising transport projects against sustainability objectives (Vassallo & Bueno, 2021), and the practices across countries vary widely (Cornet et al., 2017).

1.3 Cost-Benefit Analysis as a Sustainability Assessment Tool

Currently, several different tools exist to assess sustainability in motorway appraisal projects. There are sustainability assessment tools, such as certifications, ratings and frameworks, but also traditional project appraisal methodologies (Vassallo & Bueno, 2021). CBA is such a traditional policy evaluation tool that was not specifically designed to assess sustainability (Vassallo & Bueno, 2021).

CBA is a well-established tool for the presumedly objective assessment of alternatives in public policy appraisal. It is mainly used in ex-ante evaluations of policy options. It calculates the net monetary benefits of a policy over a predetermined timeframe, by converting all its impacts into monetary units. These monetary units are discounted towards the future to calculate the Net Present Value (NPV). If the NPV is positive; the benefits outperform the costs, and the project is considered desirable. CBA has been deemed rigorous, transparent, and formal, which provides a tangible and rational valuation of costs and benefits (Bueno et al., 2015). Traditional CBA focuses on direct financial costs and benefits and many countries mandate this economic assessment for the appraisal of public policy (Vardakoulias, 2013). Social CBA is an extension of CBA, that aims to incorporate more social and environmental impacts, both tangible and intangible. It is important to monetise all impacts and consider all in- and outputs (Browne & Ryan, 2011; Bueno et al., 2015). In the Netherlands, motorways are appraised using a social CBA (NL: MKBA). CBA and sCBA are used interchangeably throughout the literature since strictly economic CBAs are not prevalent in public policy anymore.

While CBA was traditionally not designed with sustainability at its core, sustainability principles are being applied (Bueno et al., 2015; Vassallo & Bueno, 2021). Even though the use of CBA as a sustainability assessment tool is seldom found (Hauck et al., 2016), it can be used to assess the three pillars of sustainability (Hoogmartens et al., 2014). Henke et al. (2020) use cost-benefit analysis to make an eco-rational decision. Bueno et al. (2015) studied the suitability of multiple tools for sustainability appraisal. They found that CBA performed acceptably in all five criteria they used: completeness, life cycle, trade-offs, transparency, and adaptability.

Other literature focuses on the limitations of CBA as a sustainability assessment tool. These limitations include the ethical limitation of using a utilitarian conception of welfare, and the practice of discounting, which decreases the importance of long-term impacts in the analysis (Van Wee, 2012). The timescale of

the CBA also influences the assessment of long-term impacts significantly (O'Mahony, 2021). Other concerns are related to the distribution of costs and benefits (Mostafa & El-Gohary, 2014), and the level of participation in the evaluation process (Sierra et al., 2018). Another main limitation is the level of quantification and monetisation of different impacts, and the related inclusion of impacts in the CBA. Economic impacts are quantified and monetised, but while some environmental and social impacts can be quantified, they are hard to monetise (Bueno et al., 2015; Vassallo & Bueno 2021). CBA is biased towards easily quantifiable direct costs and travel time benefits and may underestimate environmental impacts (Browne & Ryan, 2011; Annema & Koopmans, 2015). Different methods are used to assess the environmental and social impacts of CBA. For greenhouse gas emissions, valuation can be done using the prices caused by a tax or a cap-or-trade system. Methods more suitable for long-term assessment are the Damage Cost method and the Avoidance Cost method (Nocera & Cavallaro, 2012).

2. Problem Statement & Research Objective

Prioritizing more sustainable alternatives in motorway projects is important and necessary, but there is no standardized method for assessing the sustainability of alternatives in these projects. A complete overview of sustainability assessment is necessary to inform the public about the sustainability impacts of different alternatives. Currently, CBA is one of the most institutionalised and most used appraisal tools in motorway appraisal projects. While the scientific literature shows it is possible to use CBA as a sustainability assessment tool, there are also limitations, disadvantages, and issues. Many authors focus on specific issues, disregard CBA as a sustainability assessment tool, and put forward alternative tools as solutions. Little comprehensive research has been conducted into CBA's strengths and weaknesses when assessing sustainability impacts in transport appraisal. For instance, much of the literature discusses the differences between countries' applications of CBA in transport appraisal. Furthermore, it is unclear what shape a CBA used as a sustainability assessment tool in motorway appraisal projects would take and which best practices should be followed. The design and execution of a CBA are context- and project dependent and it is unknown to what extent current CBA practices conform to the requirements that a sustainability assessment tool must meet. Especially in countries where the CBA practice is institutionalised in appraisal procedures, there is an opportunity to include sustainability impacts in transport appraisal, by improving CBA practice, instead of trying to implement completely new assessment tools. This research answers the following research question and sub-questions:

To what extent can Cost-Benefit Analysis in ex-ante motorway appraisal projects be used as a sustainability assessment tool?

I) How is CBA used in motorway appraisal projects in the Netherlands?

II) What is the state-of-the-art of Sustainability Assessment in motorway appraisal projects?

III) To what extent can CBA be used as a sustainability assessment tool - in theory?

IV) To what extent is CBA used as a sustainability assessment tool - in practice?

V) What are the most feasible improvements for CBA as a sustainability assessment tool?

3. Methodology

A literature review was carried out to (1) understand CBA practice in motorway projects in the Netherlands and to (2) understand the concept of sustainability, its assessment, and its use in ex-ante motorway appraisal projects. This data is then used to (3) create an ideal framework for sustainability assessment tools in motorway appraisal projects, which describes how CBA methodology can be used as a sustainability assessment tool. Consequently, case study research was used to (4) compare the CBA practices in the Netherlands with the ideal framework, to determine to what extent CBA can be used as a sustainability assessment tool in practice. Afterwards, an expert survey was carried out to (5) identify the most feasible recommendations for improvement. A visual overview of this structure is given in Figure 1.

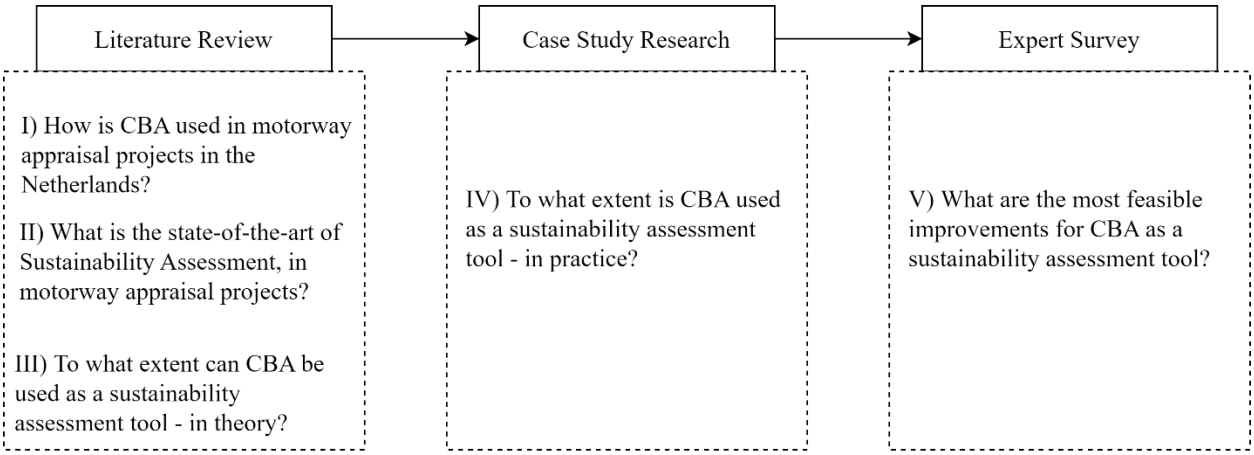

Figure 1: Overview of research questions and associated methods

3.1 Literature Review

To answer the first sub-question, a literature review was conducted on the Dutch guidelines and the use of CBA in motorway appraisal projects. General CBA theory was combined with the Dutch guidelines and the Dutch policy framework for motorway appraisal. For the second sub-question, a literature review on the concepts of sustainability, sustainable development, sustainability frameworks, and their application within CBA practice, specifically for motorway appraisal, is given. Two sets of criteria for sustainability assessment tools were found and combined into one overlapping set of criteria. This set was operationalised using other CBA literature to derive the ideal CBA sustainability assessment tool. By comparing the set of criteria with the best practices in CBA, the third sub-question could be answered.

The literature review was conducted using desk research, which is characterized by using and reflecting on the work of others (Verschuren et al., 2010). This methodology made the review systematic and transparent, preventing outcome bias. Table 1 describes the keywords and requirements applied in the source selection. Sources have been used for answering multiple sub-questions. The focus for answering question 1 will be on guidelines and reports for CBA practice since they are more extensive than scientific papers.

Table 1: Source search strategy

Question	Included sources	Databases	Keywords	Selection and exclusion criteria for all sources
1	Reports and guidelines from advisory bodies, government agencies and review papers	Websites of government, agencies	Cost-benefit analysis, procedure, motorway projects	English or Dutch Concern a Dutch or international context
2	Scientific literature (focus on review papers), methodology websites	Web of Science, Google Scholar and ScienceDirect	Sustainability assessment, methodology, motorway, ex-ante appraisal, best practices,	Preference for papers published no more than 15 years ago Preference for review papers Preference for large N studies, as opposed to single-case or pilot studies
3	Scientific literature	Same as 2	Models, multi-actor, decision-making, wicked policy problems, public values, motorway development	A preference for influential studies with multiple citations

3.2 Case Study Research

The practical application of CBA differs from country to country, application to application, and project to project. Apart from projects and problems, the organisations and people involved change as well. To answer the fourth sub-question, empirical research was necessary. Case studies were carried out to compare the application of CBA in the Netherlands with the ideal framework previously derived from the literature.

3.2.1 Case Selection

When doing case study research, case selection is important. For this study, the cases had to meet the following requirements:

- Concern only motorway projects (e.g. new route, lane widening, redesign of intersections). This requirement excludes railway projects, shipping projects or strategic policy programmes
- Concern projects, with an Exploratory Study. This excludes fast-track procedures in which no alternatives were considered or CBAs that were used to apply for national subsidies
- Concern projects that are no older than 2013, meaning they do not include any outdated CBA practices. In 2013 a major revision of the Dutch CBA guideline was published (Romijn & Renes, 2013), which standardized CBA practice in motorway projects.
- CBA documentation is available, preferably in a separate report.

The selection started with the most recent version of the Multi-Year Program of Infrastructure, Planning and Transport (Ministerie van Infrastructuur en Waterstaat, 2021). This document contains an overview of all important ongoing national infrastructure projects in the Netherlands, in four categories: roads, railways, waterways, and water management. The projects have a completion status, ranging from conceptualization to completion. The MIRT from 2021 contains 43 motorway projects. After analysis, three projects were excluded since they did not concern changes to physical infrastructure. The remaining 40 projects were

analysed for their suitability. Of the remaining 40 projects, eight projects met all requirements. 27 out of 40 projects did not have a CBA available, either because it was not conducted due to political decisions, or because the CBA was not published. Some Exploratory Studies are ongoing, and the CBA remains to be published. An overview of the case selection is given in Figure 2. A quick scan of the cases is given in appendix 11.1.

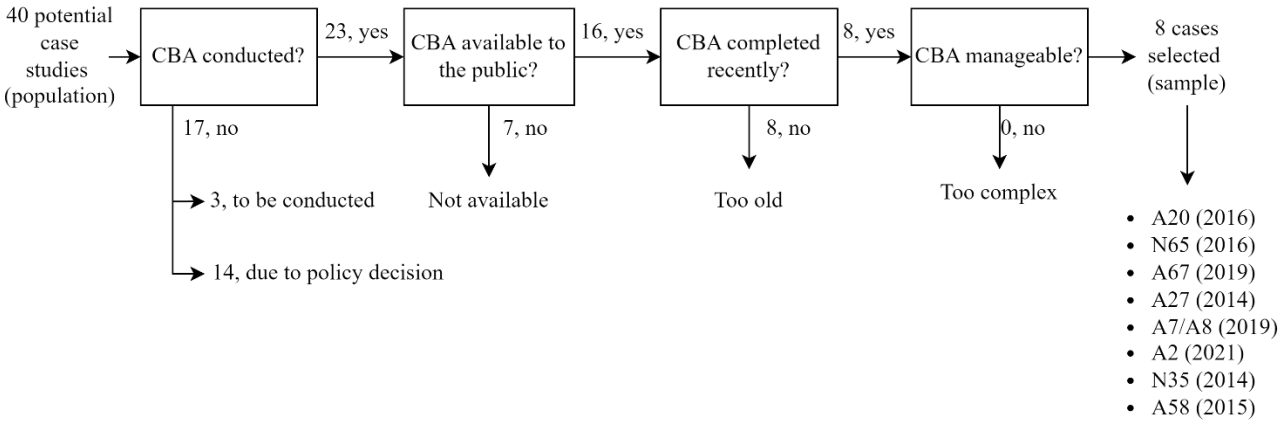

Figure 2: Overview of case selection with filters for availability, completion year and complexity

3.2.2 Data Collection & Analysis

For the case studies, the two main data collection methods were document analysis and semi-structured interviews. The data describes the case context and the practices related to each of the criteria from the ideal framework. Furthermore, data was gathered on the reasoning behind certain practices and choices, so that potential improvements could be identified. The sources used were:

- For the case context: the problem definition, location, main alternatives, results, and Preferred Decision were relevant data. The sources used to gather this data were the CBA report of the case, the Decision to Start policy document, and the interviews.
- For the CBA practice data, each criterion of the ideal framework required data on the method of estimation, method of monetization and sources for any numbers used. The sources for this data were the CBA report and underlying analyses, such as the EIA and Decision to Start, as well as the interviews.
- For the data on the effectiveness, usability and practicality of possible improvements, the main source was the interviews.

The main sources were the CBA reports and Exploratory Study documentation since these documents are traceable, ensuring transparency in the research. However, not all necessary data was available in writing. Semi-structured interviews with some individuals involved in the CBA uncovered information not publicly available. The interviews were also used to validate the already gathered data. The interviewees were selected based on their involvement in the cases and the CBA. An overview of the data types, the collection methods, and the sources to be used are given in Table 3.

It is important to note that no interview was conducted for the case N35 Nijverdal - Wierden since no contact could be made with the executors of the CBA. Hence, the only source for this case is the CBA report.

Table 2: Data to be collected, the collection method and the potential sources

Data Type	Method	Source
Data concerning the case context - What transport problem in which location was the motorway project meant to solve? - Which alternatives were considered? - What were the results of the CBA? - Which alternative was chosen as the Preferred Decision?	Document analysis & Interview (validation)	Decision to Start CBA report
Data concerning the CBA methods used, for each criterion of the ideal framework - Whether the criterion was considered, and in what way (method of estimation, method of monetization, sources for any numbers used)	Document analysis & Interview (validation)	CBA report EIA report
Data concerning the feasibility of improvements - Whether the proposed changes would be an improvement regarding - Whether applying the changes would be possible in terms of extra resources needed	Expert Survey	Consultants for the Exploratory Study and CBA experts

The data regarding the case context is descriptive and structured to provide a chronological overview of the policy process, as well as to answer the questions in Table 2. The data on the CBA practices needed to be compared to the ideal framework for CBA as a sustainability assessment tool to identify the similarities and differences. The degree to which the CBA practices in the cases conform to the criteria of the ideal framework is described as: (1) inadequate, (2) insufficient, (3) sufficient and (4) sustainable. Because knowledge of the criteria is necessary to comprehend the allocation of these scores, the framework for attributing these scores is given in the results section.

For every criterion, for which the ideal framework and the case differed significantly, without reasonable explanation, a question was written down. The questions were then transformed into an interview protocol. The interviews were transcribed and translated into English (appendix 11.6). These questions validated the findings and inquired into the reasons for the discrepancy. This data was used to adjust the scoring of the CBA criterion. For each case, the scoring per criterion was determined and described in tables (appendix 11.5). With this, the overall scoring of CBA practices in the Netherlands was determined. The score for each criterion and additional knowledge gathered in the interviews were used to suggest improvements that would bring practice closer to the ideal framework.

3.2.3 Validity & Reliability

The design of the case study had to ensure the validity and reliability of the findings and results. Reliability deals with the replicability of the case study findings, while validity concerns whether the case study accurately measures the real-life phenomenon it researches. It ensures that findings are trustworthy and robust. To ensure the reliability of the findings, the process for analysis has been clearly described and the data has been included in the appendices so that any other researcher will be able to replicate the research.

Construct validity refers to the extent to which the study measures what it claims to measure. This is ensured by the fact that the case studies are based on a literature review of the concepts of sustainability and CBA. *Internal validity* refers to the extent to which the findings can be attributed to the independent variables, rather than to extraneous variables. *Conclusion validity* refers to the extent to which the conclusions drawn

from a statistical study are based on the evidence collected. Since the case studies do not focus on causal relationships, these types of validity do not apply. *External validity* refers to the extent to which the findings can be generalized to other cases or populations. The case studies follow the prescribed methodology and therefore the results can be generalized to other cases in which CBA is used to compare alternatives in motorway appraisal projects. The interviews generalize the findings towards other cases and wider Dutch CBA practice.

3.3 Expert Survey

The case study results indicate which improvements should be made to bring the CBA practices closer to the ideal framework for a sustainability assessment tool. However, the feasibility of these improvements is not known. The improvements are based on only eight cases, so these findings might not be fully replicable to wider CBA practice. Other factors could explain why the CBA practices are not in line with the ideal framework, which would make the improvements inapplicable. To answer sub-question 5, additional data needed to be gathered.

The data could have been gathered through a pilot case study, in which the improvements could be tested, but this would not have been useful for additional validation of the case study results. Another good method would have been to conduct additional interviews with CBA experts, potentially in a focus group. However, because of time and resource limitations, this information had to be gathered using a survey of expert opinions. This was not a traditional type of survey that draws conclusions for a larger population through a sample of that population and statistical analysis. Instead, it approximates a structured interview. An overview of this research phase is given in Figure 3.

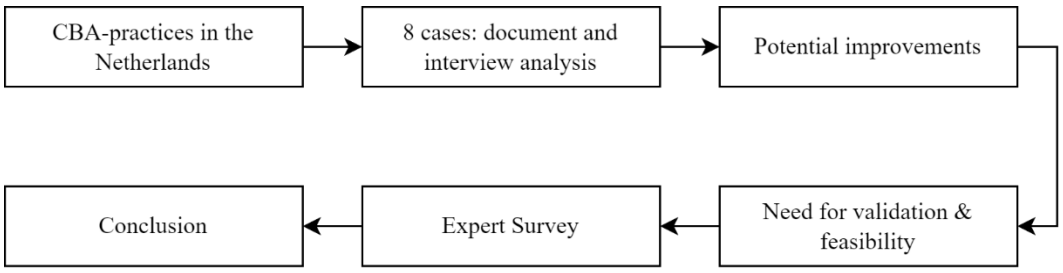

Figure 3: Description of information needed regarding the feasibility of recommendations

3.3.1 Respondents

The respondents of the expert survey were selected based on the knowledge of the researcher. All the identified participants were asked to refer additional experts that were willing to take part in the survey.

- The five interviewees from the case studies were selected, as they work with CBA in their jobs and expressed their availability for further input in the research.
- The second group of participants was identified through a meeting regarding a change to the Dutch CBA guidelines which the researcher attended. This meeting concerned the inclusion of Broad Prosperity in Dutch CBA practice, which is closely linked to sustainability. This group consists of 16 eligible experts. These experts have a larger affiliation with sustainability and are therefore more likely to participate in the survey.
- A final group of experts, that were marked as people of interest during the case study research and literature review, was also asked to participate.

In total, the expert survey was distributed to 30 participants, of which 14 responded (response rate 47%). Their specific knowledge of CBA practice in Exploratory Studies had to be vetted. The respondents were asked to validate their expertise in CBA practice in the Netherlands, with three questions related to their type of employer, involvement with CBA, and years of experience. The response was anonymous to allow for maximum openness in answering, meaning the responses cannot be linked to the respondents.

3.3.2 Design & Analysis

The survey was designed in Qualtrics. For each potential improvement, the respondents indicated their level of agreement on a four-point scale, ranging from strong disagreement to strong agreement. If their answers were anything other than strongly agree, a follow-up question was asked to explain their choice. A fifth option was to not indicate a level of agreement, ensuring that respondents could refrain from answering due to a lack of understanding. The last question was a multiple-choice question, asking the participants to choose at least three out of all improvements, that they deem feasible. In Microsoft Excel, the responses were coded into a value of 1 to 4. Respondents that indicated they did not understand the improvement were excluded. A stacked bar chart was made using this data to indicate the proportion of the respondents that agree or disagree (appendix 11.7). The level of agreement was determined based on the proportion of the respondents that agreed to some extent with the improvement, either somewhat or strongly. This was combined with the response to the multiple-choice question. The difference between the answers to these questions was determined as a proxy for the certainty of the respondents' opinion, to account for irregularities in the responses. The resulting average feasibility, certainty, as well as argumentation provided by respondents, were used to group the recommendations into two groups: *feasible* and *moderately feasible*. *Feasible* means that the improvements can and should be implemented immediately, while the *moderately feasible* improvements require different levels of additional research and clarification to implement them into CBA practices effectively and efficiently.

4. Literature Review

The following sections describe the results of the literature review. First, the general CBA practice in motorway projects in the Netherlands is explained. Then the concept of sustainability is reviewed in the context of motorway appraisal. Consequently, the criteria for sustainability assessment tools in motorway appraisal are described and the ideal framework for CBA is developed.

4.1 CBA in motorway appraisal in the Netherlands

CBA is used in public policy-making for the efficient allocation of resources: to assess whether the benefits of a motorway project outweigh its direct and indirect costs. It is used to compare the effects of proposed interventions against the reference scenario (NL: nulternatief), a situation without the intervention. CBA is not typically used to determine whether a policy is effective, but rather whether it is efficient. CBA is a widely used appraisal tool for choosing between different alternatives in transport planning (van Wee, 2012; Mackie et al., 2014; Jones, Moura & Domingos, 2014; Browne & Ryan, 2011). It has been credited with overcoming structural, cognitive, and process-related limitations and biases (Mackie et al., 2014). CBA is based on the utilitarian concept of welfare. Welfare is a philosophical concept used to describe the well-being of people. Markets are used to determine how much welfare a certain item supplies an individual with. It describes 'the willingness of individuals to give up one good or service for another'. Some welfare goods have well-determined real-life markets underpinning their valuation, but other goods are not offered on real-life markets. Hence, other methods are used to value these goods, such as stated preference methods (contingent valuation, based on Willingness-To-Pay) or revealed preference methods, such as hedonic analysis or the costs of compensation. The utilitarian concept results in welfare being measured as the

aggregated well-being of all individuals. Whom that welfare serves is not taken into account. Despite ethical concerns, utilitarianism is perceived as a (semi)objective theory, since it purposefully does not focus on anyone's benefits or costs in particular. In CBA, project impacts, benefits and costs are converted into monetary values. When summed up or aggregated, these values give a final cost-benefit ratio for each policy option, which makes the comparison of different alternatives simpler for policymakers. An important aspect of CBA is the use of discount rates. Inflation and a minimum return on public investment require the costs and benefits to be discounted into the future. If impacts were not discounted, any project in which the initial yearly benefits outweigh the costs would become profitable at some point. In the Netherlands, motorway appraisal follows the Infrastructure Planning Act (Hobma & Jong, 2016). In this framework, the Decision to Start the project is released by the government after approval by the parliament. The Decision to Start contains a problem analysis, project goals, planning, and information on the available budget. After this, the Exploratory Study, which focuses on the conceptualization of alternatives and evaluation of the best alternative, starts. The Exploratory Study concludes with a Preferred Decision, which describes the alternative chosen to solve the transport problem. The phases of an Exploratory Study are provided in Figure 4. After the Decision to Start, the analytical phase, in which several measures are compared to the primary goals of the project commences. This list of possible measures is published in the Note on Scope and Detail (NL: Notitie Reikwijdte en Detailniveau). A participatory process can be used to collect information from stakeholders and the environment and the legal right of citizens to respond to the Note on Scope and Detail with Views is protected (NL: zienswijzen). After this first filter (NL: zeef) several alternatives are transferred to the assessment phase. In this phase, an Environmental Impact Assessment is conducted, and the CBA is introduced in the policy-making process. It must be said that the recommendation is to include the CBA in the analytical phase to aid in the policy process (CPB, 2013), but this is often not the case. The results of this phase are called the second funnel. The Ministry of Infrastructure and Water Management takes note of all the available information and decides on the Preferred Decision, which also has to be approved by the Dutch parliament.

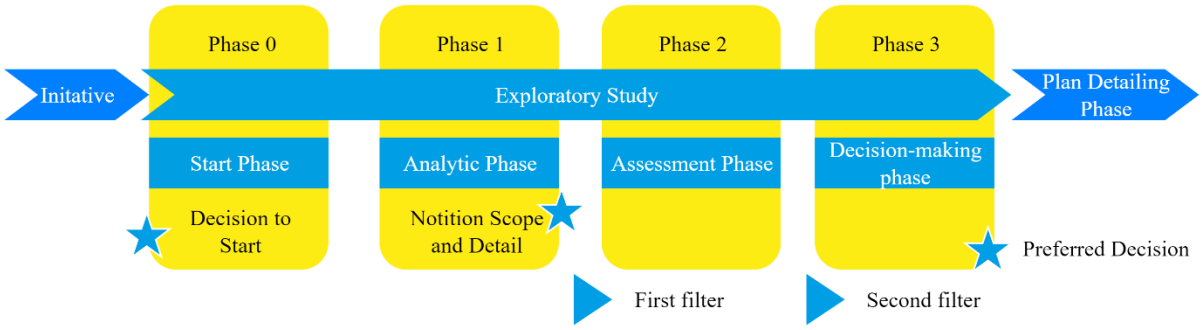

Figure 4: Different phases in an Exploratory Study. The CBA takes place at the end of the assessment phase (NL: Beoordelingsfase). Adapted from Ministerie van Infrastructuur en Waterstaat (2023)

The general guideline for the CBA methodology in the Netherlands was published by CPB Netherlands Bureau for Economic Policy Analysis in 2013 (CPB, 2013). In 2022, an addendum to this framework was published, focusing on 'broad prosperity' in CBAs, which closely relates to Sustainable Development. The CPB also developed WLO-scenarios (NL: Welvaart en Leefomgeving), which are two scenarios that describe the general trends and future developments for the Netherlands. The two main variables in the scenarios are expected economic growth and population growth. The low and high economic growth scenarios, Regional Communities (RC) and Global Economy (GE) are used as scenarios in CBAs for motorway appraisal projects. The road managing agency of the Netherlands, Rijkswaterstaat has published

several guidelines for CBAs in infrastructure-related fields. It has also commissioned multiple studies into the inclusion of specific effects in the CBA methodology. The Dutch framework for the general execution of a CBA in the assessment phase of an Exploratory Study consists of nine steps (Eijgenraam et al., 2000; CPB, 2013). This framework is given in Table 3.

Table 3: Description of CBA methodology in the Netherlands

Analytical Step		Description
1.	Problem Analysis	This includes the formulation of the problem. The problem is then translated into operational objectives, and direct limitations and hard requirements are identified. Often the problem is congestion or unsafe situations.
2.	Problem Definition	This step describes the functional elements of solutions that should be evaluated. Here the alternatives and time horizon for the project are defined. It also includes the description of the situation if there are no changes made, the so-called reference scenario (NL: nulalternatief).
3.	Identification of project impacts	This step prescribes the analysis of direct, indirect, and external effects the project might have. It also includes an overview of who will be affected by each effect. This is to aid political decision-making in later phases.
4.	Determining relevant exogenic developments	This analysis concerns all external developments that will limit or amplify the project effects of the previous steps. Since transport assets have a long service life, the focus is on long-term economic developments and international changes in economic and environmental policy.
5.	Assessment and monetization of project impacts	This step concerns the preferably quantitative evaluation of the project impacts of step three. The focus here is on the assessment and monetization of direct and indirect effects. Direct effects concern the project owners, investors, and residents. Indirect effects impact regional and national economies. For the assessment of external effects, the results of the Environmental Impact Assessment (EIA, NL: Milieu-effect rapportage) can be used.
6.	Assessment of project investment costs	This element deals with the life cycle costs for construction, maintenance, and end-of-life.
7.	Discounting and aggregation	This step contains the actual economic assessment of the total benefits and costs.
8. 9.	Variant & Risk Analysis	This is related mostly to scenario-based analysis and the inclusion of flexibility in the schedule. Other tasks may include the evaluation of public-private partnerships and creating a basis for ex-post project evaluation.

4.2 Sustainability Assessment

The term sustainability has been alluded to as far back as the 18th century, in forest management (Spindler, 2013). In the late 20th century, it got major international political attention, as sustainability became a new framing for balancing the consequences of short-term economic growth with ecosystem proliferation, as well as existing inequality and worldwide poverty (Du Pisani, 2007; Quental, Lourenço & da Silva, 2011). One of the first internationally accepted publications on sustainable (economic) development is the Brundtland Report. In this report, sustainable development is described as development that 'meets the needs of the present without compromising the ability of future generations to meet their own needs.' (World Commission on Environment and Development, 1987, p.16). This definition was developed to reach

a political consensus. While it is universal, it was deemed too broad for practical use and lacked theoretical underpinning (Purvis, Mao & Robinson, 2019). The field of sustainability assessment emerged as a framing of impact assessment to evaluate if sustainability goals were being met in a wide variety of applications. Different methodologies and tools were developed for the evaluation of sustainability performance at different institutional levels, ranging from individuals to governments (Bond, Morrison-Saunders & Pope, 2012). Sustainability assessment is defined as the process of identifying, measuring, and evaluating the potential impacts of alternatives for sustainability (Devuyst, 2000). All sustainability assessment tools are based on an understanding of what sustainability means and how it should be applied to our understanding of Earth's socioeconomic system (Ness, Urbel-Piirsalu, Anderberg, & Olsson, 2007).

4.2.1 Definition & Frameworks

The Brundtland Report did not outline a specific strategy to foster sustainable development. As a result, several attempts were made to divide sustainability into several dimensions that describe humankind's influence on Earth's socioeconomic system. Waas et al. (2011) refer to them as sustainability models. The dimensions of sustainability are a form of compartmentalization, which means to divide information from a messy, interconnected reality into discrete compartments (Smyth, 2021). Compartmentalization of issues for easy decision-making is common because of our rational-thinking structures. For a concept as complex as sustainability, this is no different. Different views on sustainability lead to different dimensions (Salvia, Leal Filho, Brandli, & Griebeler, 2019), while some reject compartmentalization entirely and focus on a holistic approach.

The compartmentalization of sustainability helps identify which sustainability impacts of a project should be evaluated. These are referred to as sustainability criteria, which are monitored with sustainability indicators. Indicators are measurable attributes of sustainability impacts. An indicator can be quantitative, semi-quantitative, or qualitative and varies in level of detail and scope. To illustrate: 'a sustainability indicator can be defined as a [any] measurable aspect … that is useful for monitoring changes in system characteristics relevant to the continuation of human and environmental well-being' (Fiksel, Eason, & Frederickson, 2012, p.6). A proper sustainability assessment tool considers all relevant sustainability indicators to the greatest detail possible.

A main consideration in sustainability tools is whether different forms of capital or criteria can be exchanged for each other and whether aggregate sustainability performance can be measured. In weak sustainability, natural capital is an orderly stock of resources, which, given the appropriate technology and innovation is in place, is fully replaceable with capital created by humans. In most economic approaches, natural and social capital are exchangeable with produced capital (Dietz & Neumayer, 2007; Pelenc, 2015; Kuhlman & Farrington, 2010). From the strong sustainability perspective, a minimum amount of natural and social capital is essential and should be protected against replacement by economic and human capital.

Over the years, different sets of dimensions of sustainability have been developed independently of each other. The most recent framing of sustainable development, the Sustainable Development Goals (SDGs) for 2030, is devoid of any central compartmentalization of sustainable development (United Nations, 2015). A critique of the SDGs is that they are too broad and do not define a 'clear' solution space of acceptable practices, possibly because of a lack of compartmentalization (van Vuuren et al., 2022).

A popular topology is the Three Pillar Framework, focusing on the economic, social, and environmental dimensions of sustainability (Purvis et al., 2019; Strezov et al., 2017; Alhaddi. 2015). The presentation of these three aspects as 'pillars' is common because it describes the interrelation between these three dimensions (Waas, Hugé, Verbruggen & Wright. 2011). They are all pillars of the same 'temple of

sustainability' and therefore are all equally important. This three-pillar approach is well-used and therefore a well-respected framing of sustainability. Many small-scale, project-level tools have been developed using this compartmentalization. Most national agencies have used the three-pillar framework synonymously with sustainable development (Purvis et al., 2019). For private organizations, the framework was developed into an accounting strategy, often referred to as the Triple Bottom Line, or the three P's: people, planet, and profit (Elkington, 1994). A different representation of the three pillars is described using a Venn diagram, in which economic growth cannot occur at the cost of environmental and social sustainability.

In essence, the economic pillar describes that countries and organizations should strive towards economic growth, increasing the welfare of their stakeholders and citizens (Spangenberg, 2005). The environmental pillar describes the preservation of Earth's ecosystems and their functioning. It concerns the protection of flora and fauna and the services they provide humankind with (Morelli, 2011; McGranahan & Satterthwaite, 2002; Joumard, 2009). The social pillar describes the human values of our socio-economic system. It concerns the provision of human rights and equity between humans, in addition to cultural and traditional values (McKenzie, 2004; Pawłowski, 2008).

The critique of the three-pillar framework includes that it has not led to desirable sustainable action (Kuhlman & Farrington, 2010), has contributed to the continued exploitation of ecological systems and resources, and promotes greenwashing by private companies (Shnayder, Van Rijnsoever, & Hekkert, 2015; Willekes, Jonker & Wagensveld, 2020). Another major criticism is that the social pillar is underrepresented in practice (Boström, 2012). Numerous authors (e.g. Pawłowski, 2008; Purvis et al., 2019; Singh, Murty, Gupta & Dikshit 2009) have proposed the inclusion of additional dimensions into the pillar framework, such as a technical, political, or legal dimension. However, few of these concepts are a part of sustainability assessment tools used in practice. In response to the critique of the three-pillar framework, the Circles of Sustainability framework was developed. The UN commissioned the development of this framework for urban sustainability, with which cities can monitor their sustainability performance (James, 2014). The new compartmentalization had the following dimensions: ecology, economy, politics, and culture. While it is a well-accepted framework for sustainability, it was specifically developed for assessing urban sustainability. Another, separate development in defining and operationalizing sustainability was The Natural Step framework (Tynberg, 2000; Larson & Warren, 2017), by the identically named organization, in 1989. This organization described which human activities are allowed in a sustainable planetary system. The four system conditions are that nature is not subjected to (1) increasing concentrations of substances taken from the earth's crust, (2) concentrations of substances produced by society and (3) degradation by physical means. The fourth condition is the absence of structural obstacles to people's health, influence, competence, impartiality and meaning (Larson & Warren, 2017). The premise of the framework is that human life on Earth should be preserved. As such, the fourth condition is about human dignity and the other conditions concern humanity's interaction with the Earth's ecosystems. The organization advises governments and companies on how to organize their operations according to these four system conditions. For this, it uses the Framework for Strategic Sustainable Development (FSSD) itself and several tools and methodologies derived from it. The Natural Step was seen as persuasive, instead of fully science-based, with limited practical relevance as it had not been further developed (Upham, 2000). It is deemed too generic to assess sustainability in transportation systems (Illahi & Shafi Mir, 2020).

The concept of sustainable development, the different frameworks for sustainability, along with criteria and indicators, aided the development of tools that are used for sustainability assessment. Sustainability assessment tools provide a structured guideline for the comparison, evaluation, and aggregation of the available information regarding sustainability performance. The tools are based in an understanding of

sustainability, which influences the choice of sustainability criteria and indicators. The relations between the concepts are shown in Figure 5.

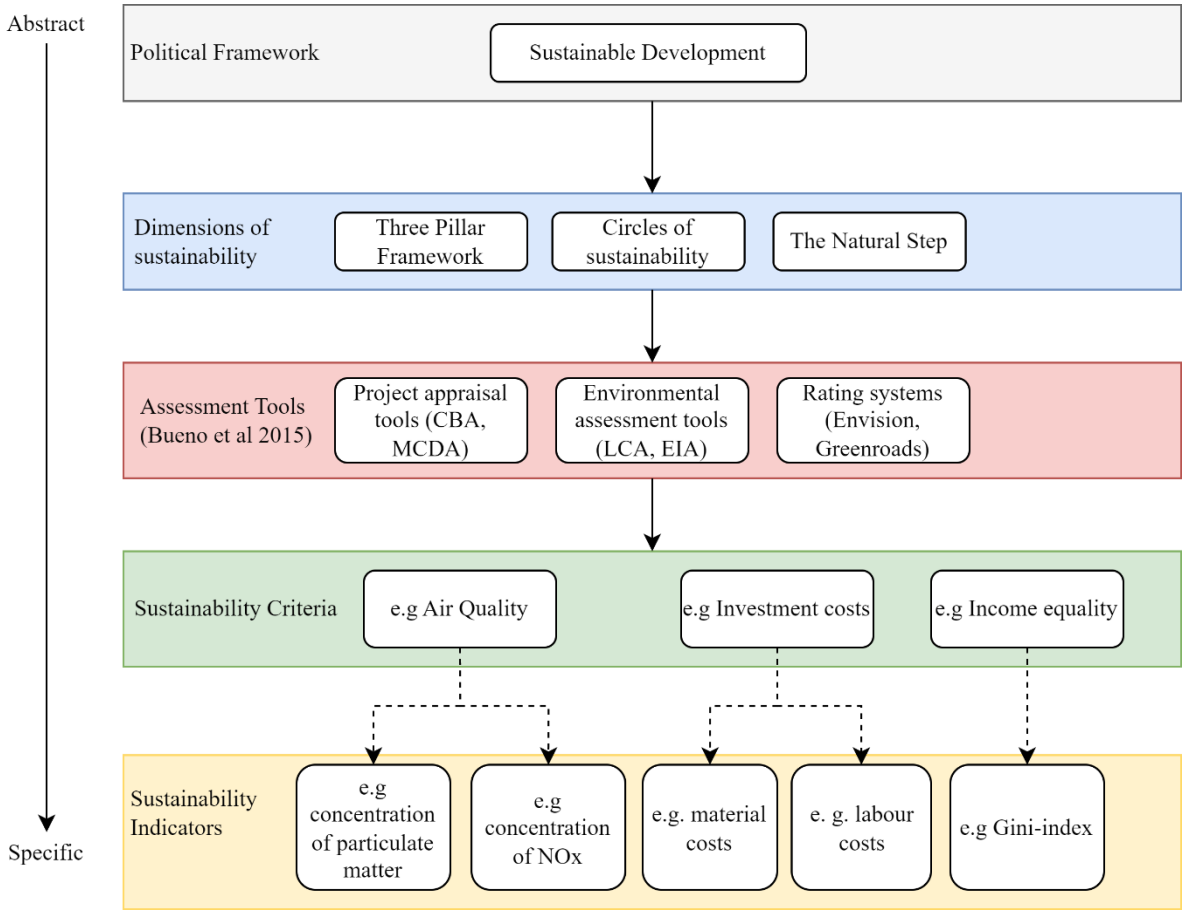

Figure 5: Description of theoretical concepts in sustainability science, ranging from sustainable development to sustainability indicators, and their interaction.

For the appraisal of motorway projects, Bueno et al. (2015) describe three types of tools that can be used for sustainability assessment, based on the three-pillar framework of sustainability. These include traditional project appraisal methodologies, tools specifically used for environmental and social assessment, and rating and certification systems. CBA is part of the first category of tools. Bueno et al. (2015) also assessed whether the tools can be used for integrated sustainability assessment in motorway appraisal projects.

All rating and certification systems are supported by different dimensions of sustainability and have widely varying assessment methodologies. Some are simply based on questionnaires. The environmental and social sustainability assessment methodologies, such as LCA, do not provide a coherent singular sustainability performance. Singh et al. (2009) refer to these methodologies as product-related, instead of integrated sustainability assessment. CBA is identified as a potential integrated sustainability assessment tool (Singh et al. 2009). Bueno et al. (2015) researched CBA as a sustainability assessment tool but stressed that further analysis and evaluation are necessary to improve its use as a sustainability assessment tool.

Singh et al. (2009) categorise sustainability assessment tools along three different characteristics: normalization, weighting and aggregation. They identify two types of tools for integrated sustainability

assessment: ones that use monetization to aggregate effects and others that use physical indicators. Another consideration for each sustainability assessment tool is the scope: time, scale, and perspective. The temporal scope is determined by which life cycle phases are considered in the assessment. The scale concerns the societal level (e.g. national, global, regional) of the analysis. The perspective concerns which entities, organizations, or stakeholders the assessment is performed for. In practice, other considerations that assessors must make are how much time and financial resources are available for the sustainability assessment.

4.2.2 Criteria for sustainability assessment tools in motorway appraisal

To further analyse CBA as a sustainability assessment tool in motorway appraisal, it is necessary to understand what requirements such a tool would have to meet. Bueno et al. (2015) defined requirements for sustainability assessment tools in motorway appraisal projects. Sala et al. (2015) also define criteria for sustainability assessment methodologies, although these are not specifically aimed at motorway appraisal projects. The two sets of criteria were combined into an overarching framework for the suitability of a tool as a sustainability assessment tool. Sala et al. (2015)'s framework also contained a criterion that was not relevant to motorway appraisal projects, so it was excluded. The final set of criteria is provided in appendix 11.2 with the sources and definitions from Bueno et al. (2015) and Sala et al. (2015). There are six criteria: (1) boundary orientation, (2) full approach, (3) strategic sustainability thinking, (4) trade-offs, (5) contextual input, and (6) transparency.

To understand and critically reflect on the set of criteria and how it affects the use of CBA as a sustainability assessment tool, existing research into the current use of CBA for sustainability assessment has been identified, summarised, and categorised along these six criteria. This gives more insight into what requirements a CBA should meet when being used as a sustainability assessment tool.

Criterion 1: Boundary orientation
Boundary orientation relates to whether the sustainability assessment tool sets reference values for the impacts (Sala et al., 2015). This provides context to the impacts and relates them to the wider decision-making context. According to Sala et al. (2013), there are three possible levels for boundary orientation: (1) no reference values, (2) a status quo scenario, and (3) policy and science-based reference values. For some sustainability impacts, such as labour standards and noise pollution, these reference values take the shape of hard legal requirements.

Criterion 2: Full Approach
Sala et al. (2015) refer to a full approach as (1) comprehensiveness, simply covering as many pillars of sustainability as possible, and (2) integration of disciplines, whether the method simply estimates one pillar, more indicators for the same pillar, or was specifically designed to take into account all pillars. Bueno et al. (2015), understand this criterion as the inclusion of all economic, environmental, and social impacts in the tool to the highest level of detail possible. Other authors identify similar impacts but express concerns about the specifics of the impact assessment.

For economic sustainability, Bueno et al. (2015) provide those impacts included in the tool should be infrastructure costs (construction/maintenance/operating), travel time cost/saving, vehicle operating cost, accident cost/saving, and macro-economic impacts. Flyberg et al. (2021) found that project results are often overestimated because assessors underestimate cost factors such as delays, geology, price inflation, complexity, scope changes, bad weather, and archaeological finds. The largest inaccuracy is in travel time savings. These are often overestimated, just as the amount of newly generated traffic (Korytarova & Papezikova, 2015; Flyberg et al., 2021). Travel models usually have trouble estimating the reliability of

travel time savings, because trips are counted equally, with no difference in valuation per trip type (Chi & Bunker. 2021). Other benefits, such as the development of local economies and maintenance cost reductions are all significantly lower contributors (Korytarova & Papezikova, 2015) and the methods in CBA for assessing long-term economic regional projects are limited (Weisbrod, 2016). However, Mackie et al. (2014) conclude that a lot of progress has been made in this regard, perhaps because transport is supposed to foster economic growth, as opposed to being a goal in itself. (Mackie et al., 2014).

For environmental sustainability, the impacts that should be considered are energy consumption, resource use and CO2 emissions, habitat fragmentation and negative effects on species, air pollution, noise pollution as well as landscape degradation and negative visual impacts (Bueno et al., 2015). Over the last decade, a move has been made to more monetary valuation of environmental impacts. The evidence base for monetary values has widened (Mackie et al., 2014). The main differences between the 7 countries that Mackie et al. (2014) researched include the different valuation of health benefits and carbon emissions. CO2 emissions can be assessed in multiple ways (Nocera & Cavallaro, 2012). However, a large problem in CBA is estimating those impacts that cannot be quantified or monetised (Mouter, Annema & Van Wee, 2013) and many of the external effects that come with increased travel and generated traffic are underrepresented in the CBA (Browne & Ryan, 2011).

For social sustainability, Bueno et al. (2015) conclude that the following impacts should be considered: community disruption, impacts on businesses and community services, employment and labour standards, distributive effects of the project, and occupational and community health and safety. The social dimension of sustainability is not well-developed for quantitative assessment in CBA. Other authors include different criteria for motorway appraisal (Colantonio, 2009; Abdel-Raheem & Ramsbottom. 2016), but these are by themselves not suitable for CBA. Commonly, CBA does not consider the distributive effects of costs and benefits (Thomopolous, Grant-Muller & Tight, 2009), although most decision-makers deem it necessary for political support from communities and stakeholders. The largest benefits, travel time savings, are subject to criticism, due to equity considerations. Some authors have advocated for the inclusion of overall accessibility gains (Martens & Di Ciommo, 2017; Martens, 2020).

In the end, Bueno et al. (2015) provide the most coherent list of impacts to be considered, including definitions. In appendix 11.3, a table with the definition per impact is provided and the differences with the original definition of Bueno et al. (2015) are provided as well.

Criterion 3: Strategic sustainability thinking

Strategic sustainability thinking is associated with assessing the sustainability impacts of a motorway project across its entire life cycle. Sustainability is at its core concerned with the effects of present-day actions on future generations. Every engineering object has a life cycle, from its first conceptualization and design to its realization, use and the end of its service life when it usually is demolished, or sometimes recycled. Life Cycle Thinking shifts the traditional focus on impacts during use to all life cycle phases, from the extraction of raw materials to end-of-life. Sala et al. (2015) also stress the importance of life cycle thinking for delivering change or sustainable solutions. This adds another level of strategy to a sustainability assessment tool, which makes it useable for sustainable design.

For CBA, authors identify that it generally focuses on initial investment and construction, while a lot of sustainability impacts can occur during its use and end-of-life, or in the extraction of raw materials. Many environmental and social impacts will stretch for much longer than the actual lifespan of the infrastructure assets. The inclusion of these long-term effects is limited because of the limited life cycle perspective and because of the discounting of effects (Cornet, Barradale, Barfod, Hickman 2017). Across European countries, there are large differences in included discount rates and time scales. (Thomopolous, Grant-

Muller & Tight, 2009). Timescales of more than 100 years are recommended since shorter timespans will bias the CBA results to those projects that are more carbon-intensive and negatively affect sustainable development (O'Mahony, 2021). Furthermore, CBA rarely includes correct residual value calculations (Jones et al., 2014), if it is even considered at all.

Criterion 4: Trade-offs

Bueno et al. (2015) stress the clarification of trade-offs in sustainability assessment tools. When the results are presented to decision-makers, the underlying relative importance of criteria should be shown and methodologically adjusted to provide decision-makers with as much information as possible. In its effort to present decision makers with a single 'go or no-go' dilemma, CBA monetises all impacts and aggregates them into a single cost-benefit ratio. However, monetization efforts for sustainability impacts are limited. This is the largest problem in Dutch CBA practice, and it causes the cost-benefit ratio to be skewed towards the economic dimension, instead of weighing all efforts equally (Mouter et al., 2013). The underlying relative weights of the indicators should be clear, provided it is possible to compare them. A study by Annema et al. (2015) found that Dutch politicians find the outcomes of CBA to be pretentious in its presentation of only one end value, instead of showing the trade-offs between different choices. Uncertainty in CBA is usually combated using different input variable combinations in different what-if scenarios. The complexity of the result increases with more scenarios. The probability of certain scenarios is usually not taken into account (Salling & Banister, 2009). Another weakness is the complexity of assessing multi-phase projects with large scopes since the level of interdependence with other projects is high (Chi & Bunker 2021).

Criterion 5: Contextual input

Bueno et al. (2015) define contextual input as accounting for the importance of local interests in a systematic way. If the local context is, for instance, concerned with the protection of a local nature area or park, specific attention should be given to assessing these sustainability criteria. It should even be given more weight in the analysis because of its importance. Sala et al. (2015) go beyond this characteristic and stress the actual involvement of stakeholders in the process.

The input of people and stakeholders matters for deliberation and argumentation, therefore making the final decision more acceptable. It is not only the technical correctness of the outcome that counts but also the social inclusion of people and stakeholders (Van Wee, 2012). The CBA needs to be at least presented and discussed by the stakeholders of the project. In the Netherlands, participants feel the government sees CBA results too much as a final assessment (Beukers, Bertolini & Brömmelstroet, 2012).

Criterion 6: Transparent Approach

Transparency is not rooted in the technical correctness of the CBA, but in the use of sustainability assessment as a decision-making tool in a democratic context. The results and methodology used should be transparent. The tools should be 'transparent, rational, and formal to minimize ambiguity — understood as the lack of clarity concerning the methodological principles — and ensure consistency and accuracy — interpreted as the closeness of measured results to acknowledged accurate results.' (Bueno et al., 2015. p.19). Sala et al. (2015) also incorporate this requirement and they focus on the communication of values that underpin the analysis. It should be clear what methodologies were used and which assumptions were made to complete it.

The results of a CBA are often presented as an objective, risk- and uncertainty-free judgement. However, it has long been clear that CBA results are always subject to large uncertainty. The communication of these uncertainties to involved parties is generally lacking. Given that model and parameter choice is a black box to stakeholders and politicians, the trustworthiness of CBA in the decision-making process is often

compromised. One of the remedies can be to standardize the methodology. For instance, in Australia, the government provides a large list of potential environmental pollutants whose impact needs to be assessed in CBA, as opposed to the European Union (Chi & Bunker, 2020). Dutch politicians also see process-related issues with the CBA analysis (Annema, Mouter & Razaei, 2015), the independence of researchers conducting the analysis and involving the public (Annema et al., 2015). Studies have shown that even when good decision bases are available, decisions are often more influenced by the decision-maker's intuition and personal or political preferences than by facts and analyses (Annema et al., 2015).

4.2.3 Best practices for CBA as a sustainability assessment tool

This section presents the best practices in CBA practice for sustainability assessment and determines to what extent CBA can be used as a sustainability assessment tool in motorway appraisal projects. The previous section has defined the criteria for such tools and additional literature has given insight into concerns for CBA. A comparison of CBA with the criteria enables the creation of an ideal framework, with the best practices for CBA as a sustainability assessment tool. These are given in Table 4Table 5. The best practices were compared with the criteria and literature from the previous section to answer the third sub-question. This is also provided in Table 4, describing whether CBA is suitable, limited, or unsuitable for meeting a criterion for sustainability assessment.

Boundary conditions can be a part of a CBA to strengthen its suitability as a sustainability assessment tool. The adoption of hard limitations for impacts, or even a sustainability framework can ensure the exclusion of unsustainable practices. Implicitly, boundary conditions are present in most CBAs and alternatives, even though they might not be referred to as such. There are project goals, such as the improvement of congestion, but also the maximum available budget, as well as legal limitations for air and noise pollution. The baseline reference scenario, with autonomous developments such as population growth, also forms a boundary orientation against which the alternatives' performance is measured.

When using the best practices, CBA is well-equipped to assess and monetise the impacts of the economic and environmental pillars of sustainability and include them in the Cost-benefit ratio. This applies to social impacts to a lesser extent. The economic effects of direct investment costs, travel time benefits, reliability benefits, vehicle costs and safety improvements are well-established in CBA theory and traffic models. Indirect economic effects can be estimated, but the process requires a significant amount of resources. For most environmental effects, methods for quantification and monetization exist within the best practices. The value of biodiversity and protected species are difficult to monetise, but the compensatory measures should at least be estimated. Air and noise pollution are straightforward to assess and monetise as well. Landscape degradation is difficult to isolate and therefore difficult to assess, though valuation is possible. The ability of CBA to estimate and present social effects is limited since social effects are generally not considered to be welfare effects. However, these effects do occur and with additional analyses, it is possible to include them in the wider CBA report. Community disruption is difficult to measure, though the ability to cross a road is one method to assess it. The impacts on business and community services are also difficult to translate into welfare effects. The same goes for occupational and community health and safety, though an in-depth analysis of labour conditions is a valid method to assess this criterion. Cultural heritage is also difficult to assess as a welfare effect since it is difficult to isolate it.

Strategic life cycle thinking can be prevalent throughout CBAs, but the focus should be on valuing effects with different discount rates and including as many life cycle phases as possible. CBA has clear prescriptions for this, although it is time-consuming and not well-implemented to use LCA tools within CBA. It is possible to show the trade-offs for sustainability with CBA, given there is a wide variety of potential solutions and sensitivity, and risk analyses are included. CBA is a technical, formal decision-

making tool. However, within the scientific literature, there are enough examples of consultation between local stakeholders and interested parties to define alternatives and effects to be focused on. Transparency is well-established within CBA practice, but it remains a technical, formal decision-making tool. With adequate referencing and explanations of the methodology, the process can become much more transparent to people that are not involved in the analysis. There should be public moments for elaboration and explanation of the results and methodology. Referencing calculation numbers and the provision of transparent documentation is necessary.

These results indicate that CBA practices in motorway appraisal projects can be used as a sustainability assessment tool. A strictly economical CBA, only few sustainability impacts would make it into the analysis. In the best practices for CBA, a wide variety of impacts are quantitatively assessed and monetised. CBA is first and foremost focused on assessing all relevant social welfare costs and benefits, even if the expressions of that welfare cannot be included in the cost-benefit ratio. The inclusion of non-quantifiable or non-monetizable effects as a qualitative, pm-post (pro memori) informs decision-makers about said effects. In combination with other (LCA) tools and enough allocated resources, CBA can evaluate the three pillars of sustainability. However, social sustainability is significantly more difficult to quantify and monetise than the economic and environmental pillars of sustainability. A focus on strategic sustainability thinking is necessary to foster the inclusion of life cycle thinking and the use of different discount rates. The grounding of threshold values for impacts in policy and evaluating a wide variety of alternatives would ensure a strong boundary orientation. CBA is limited when it comes to contextual input and transparency for a sustainability assessment tool. The methodology is technical and usually grounded in rigid policy procedures to ensure consistency in policy making. However, transparent presentation of results and methodology and stakeholder interaction throughout the process can greatly increase CBA's fulfilment of these two criteria.

Table 4: Evaluation of CBA as a sustainability assessment tool

ID	Criterion		Is CBA suitable?	Best practices for CBA	Sources
1	Boundary Orientation		Suitable	**Adopt** a clear strong sustainability framework. **Use** hard legal limitations for sustainability indicators from all three pillars based on sustainability policy or scientific goals and **use** different alternatives with a wide variety of alternatives that influence multiple sustainability indicators.	Potschin & Haines-Young (2008); Srebotnjak et al. (2010); Romijn & Renes, (2013); Bertrand et al. (2008);
2	Full approach (three pillars)		Limited	In CBA, it is possible to estimate and monetise the economic and most environmental pillars, but the social pillar is difficult to quantify and monetise.	
2.1	Economic criteria	Infrastructure costs (construction/ maintenance/ operating/residual value)	Suitable	**Estimates** based on detailed designs account for uncertainty in planning and designs. Include at least average construction time, resources necessary, manpower and transport costs. Include costs across the entire life cycle. **Monetise** using market prices	Flyberg et al. (2021); Thoft-Christensen (2012); Kjerkreit & Odeck (2015)
		Travel time cost/saving (accessibility)	Suitable	**Estimate** using traffic models and differentiate between trip types. Include reliability of savings. Include induced demand. **Monetise** using the value of time and willingness to pay.	Rijkswaterstaat (2018); Martens & Di Ciommo (2017); Mouter et al. (2013); Chi & Bunker (2021)
		Vehicle operating costs	Suitable	**Estimate** using the difference in congestion and distance. **Monetise** with fuel costs	Bueno et al. (2015)
		Accident cost/saving	Suitable	**Estimate** the reduction of accidents, based on probability. Use traffic flow and road design types and differentiate between different types of accidents. **Monetise** using costs per accident, congestion, health care costs health effects and Value of Life.	Rijkswaterstaat, (2018); Wijnen et al. (2009); Schoeters et al. (2022); Keller et al. (2021); Ustaoglu & Williams (2019);
		Macro/wider economic impacts)	Limited	**Estimate** all long-term economic effects, based on economies of scale, agglomeration and international developments. **Monetise** using company surveys of added benefits.	Rothengatter (2017); Gibbons et al., 2019; Melia (2018); Pieda Consulting (2018); Venables, A. (2017)

2.2	Environmental criteria	Energy consumption	Suitable	**Estimate** using life cycle approach, raw extraction, construction process and use, based on preliminary design characteristics. **Monetise** using market prices. This can be included in the investment costs in practice.	Arshad et al. (2021); Isler, Blumenfeld & Roberts (2022)[2]; Clinch (2004); Kylili, Angeliki & Fokaides (2017);
		Resource use (Abiotic depletion)	Suitable	**Estimate** based on preliminary design characteristics for different scarce elements. **Monetisation** is covered under investment costs, but multipliers for the scarcity of future use should be used.	Arshad et al. (2021); Isler, Blumenfeld & Roberts (2022)[2]; Clinch (2004); Kylili, Angeliki & Fokaides (2017); Vogtländer, Peck & Kurowicka (2019); Huppertz et al. (2019)
		Global Warming Potential	Suitable	**Estimate** CO2 emissions for the entire life cycle, based on LCAs. **Monetise** with various methods for the Cost of Carbon: emission trading system, mitigating measures, or damage caused.	Rijkswaterstaat (2017); Meunier & Quinet (2015); International Transport Forum (2015); Johansson, Persson & Azar (2004); Durão et al. (2019); Balcombe et al. (2018); Rennert (2021); Mandell (2011); Nocera & Cavallaro (2012);
		Habitat fragmentation and negative effects on species	Limited	**Estimate** based on habitat loss, including nesting grounds and food supply. **Monetise** using mitigating measures, or intrinsic value of species	CE Delft & Arcadis (2018); Spangenberg & Settele (2010);
		Air pollution (acidification & health)	Suitable	**Estimate** using equivalent emissions over life cycle relate to effects on nature loss and health. **Monetise** using mitigating measures and health care costs	Rijkswaterstaat (2017); Verhoef, E. (1994); Schucht et al. (2015); Sengupta & Mandal (2005);
		Noise pollution	Suitable	**Estimate** with noise pollution models, locally. **Monetise** using health effects and comfort	Hunt et al. (2016); Berry & Sanchez (2014); Istamto, Houthuijs, & Lebret, (2014); Hofstetter & Müller-Wenk (2005); Mouter et al. (2019);
		Landscape degradation has negative impacts (visually)	Limited	**Estimate** effects on the existing landscape and its cultural value. **Monetise** using mitigation measures, hedonic analysis or surveys	Farjon & Sijtsma (2018); Ecorys (2009); Löfgren et al. (2018)

2.3	Social criteria	Community disruption (accessibility)	Limited	**Estimate** direct, indirect, and wider effects of barrier function. Direct effects include crossing and passing effort. Indirect effects are the consequential changes in trips and destinations and wider effects are the resulting macro-socio-economic influences in health and activity. **Monetise the** direct effects of the travel time change.	van Eldijk, Gil, & Marcus (2022); van Wee & Geurs (2011)
		Impacts on businesses and community services	Limited	**Estimate** local effects of relocation of activities and businesses and potential loss of clients. **Monetise** with necessary compensation and investment costs of relocation	Rijkswaterstaat (2017);
		Distributive effects of the project	Limited	**Present** the costs and benefits relative to the stakeholder groups they fall to. No multiplier for 'unequal' alternatives exists, based on utilitarianism.	Rijkswaterstaat (2017); Thomopolous, Grant-Muller & Tight (2009); Bueno et al. (2021)
		Occupational and community health and safety	Limited	**Include** effects of labour standards on health and the probability of accidents throughout the life cycle. **Monetise** using healthcare costs	van der Velden & Vogtländer (2017); Ikpe, Hammond, Proverbs (2008);
		Cultural heritage (landscape)	Limited	**Estimate** loss of culturally viable land and necessary research. **Monetise the** value of cultural heritage with a contingent valuation or revealed presence	Tišma et al. (2021); Farjon & Sijtsma (2018)
3	Strategic sustainability thinking		Suitable	In CBA the inclusion of life cycle thinking as well as lower discount rates for external effects covers the criterion of strategic sustainability thinking	
3.1	Cradle-to-cradle life cycle thinking for all project materials		Suitable	**Include** sustainability impacts for all phases of the life cycle, from raw extraction and processing of materials, construction, usage phase and end-of-life	Hoogmartens et al. (2014); Cornet, et al., 2017);
3.2	Lower/different discount rates for environmental effects		Suitable	**Use** lower discount rates for environmental effects with a low substitution rate and high certainty	(O'Mahony, 2021); Lueddeckens et al. (2021); Drupp et al.,(2018); Groom et al. (2022); Almansa & Martínez-Paz, (2011).

4	Rigorous trade-offs: present relative weights of costs and benefits	Limited	**Present** different variation, sensitivity, and risk analyses to indicate the uncertainty in alternatives. **Choose** a wide variety of alternatives to indicate trade-offs. **Present** reference scenario to indicate the base level of effects	Bueno et al. (2015)
5	Contextual input	Limited	Through stakeholder participation and inclusion of local interests, this can be ensured, but the national context and established methods are often necessary for the consistency of policy decision-making	
5.1	Stakeholder Involvement	Limited	**Include** stakeholder wishes in an early phase through a participatory process to (1) use as argumentation for researching some effects more than others and (2) define alternatives.	Zafar et al. (2020); Mathur, Price & Austin (2008); Nguyen (2019); Beierle (2002); Carolus et al., 2018
5.2	Local variation of weights and priorities	Limited	**Focus** research on impacts that are relevant to the location of the project.	Hansson (2007); Bueno et al., 2015; Mascarenhas (2010);
6	Transparent approach	Limited	The methodology is technical, and explanation and presentation can warrant transparency when using CBA	
6.1	Presentation of results to the public	Suitable	**Present** results of the CBA to the public and interested stakeholders. **Provide** the possibility to ask questions and **answer** them. **Discuss** effects that were not included or monetised.	Volden (2019); Cecot & Hahn. (2020);
6.2	Explanation of methodology, uncertainty and choices	Limited	**Provide** references for key figures (NL: kengetal). **Explain** how effects were calculated and why. **Provide** a paper/research trail for the reader to follow	Rijkswaterstaat (2017); Cecot & Hahn. (2020); Deighton-Smith & Vickerman (2022); Pintér et al., 2012;

2concerns railway infrastructure

[3]not in Bueno et al. (2021)

5. Case Study Research

This section contains the results of the case study research, arranged per case. The specific sources per case are provided in appendix 11.4. First, the ideal framework will be adjusted to be able to extract meaningful information from the cases.

5.1 Ideal Framework

The ideal framework focuses on the best possible practices for CBA when used as a sustainability assessment tool. To extract meaningful information from the cases, further specification of the different possibilities CBA practitioners have when a CBA is necessary. Based on the ideal framework, a four-level scoring system was developed.

- **Score 1** describes the lowest inclusion of sustainability assessment in the CBA: to not mention a criterion at all or give any attention to the specific criterion. This is deemed **inadequate**
- **Score 2** refers to the fact that the CBA practitioners acknowledge the existence of a criterion, but do not assess it in a significant way, so it is not reflected in the outcomes of the CBA. These working methods are inherent to traditional CBA and do not specifically sustainability assessment. This is deemed insufficient. For some criteria, this means they are only assessed qualitatively, while for other criteria it means that it is business as usual.
- **Score 3** generally describes those practices that pay significant attention to the criterion, but do not meet all the requirements of the best practices from the ideal framework. This includes practices that are seen as advancements towards the best practices, but do not them.
- **Score 4** describes the best inclusion of a criterion: to meet the best practices from the ideal framework for the category suitable, which means that the CBA is being used as a sustainability assessment tool.

The origin of the boundary between scores 2 and 3 for criterion 1 boundary orientation is rooted in the fact that no contemporary motorway appraisal projects are conducted without any boundary conditions. All of them include budget and congestion alleviation (political boundary) and noise and air pollution legal limitations since that is the law in the Netherlands. However, while these boundary conditions might show similarities with other sustainability impacts, their inclusion is not included from a sustainability perspective. As such score 3 is regarded as including more boundary conditions than the go-to impacts, while score 4 refers to larger strong sustainability goals such as CO2-neutrality. The framework used for the comparison of the CBA practices in the cases to the ideal framework with best practices is given in Table 5.

Table 5: Analytical Framework for Comparison of CBA Practice with the ideal framework

ID	Criterion	Score			
		1= Inadequate	2 = Insufficient	3 = Sufficient	4 = Sustainable
1	Boundary Orientation	There are **no** boundary conditions regarding sustainability	**Less than 4** boundary conditions for sustainability impacts, without mentioning a sustainability framework	**More than 4** boundary conditions, without mentioning a sustainability framework	A clear sustainability framework is adopted, with strong sustainability limits **for all** sustainability impacts
2	Full approach	**No** attention to economic, environmental and social criteria	Sustainability impacts are included, **but only qualitative**	Sustainability impacts are **quantified and monetised,** but not according to the best practices from the ideal framework	Sustainability impacts are **quantified and monetised like the best practices**
3	Strategic sustain-ability thinking	**Only one** life cycle phase and a single discount rate without reference are included	**Two life cycle phases,** usage and construction are included and only one discount rate, with reference	**Three life cycle phases** included different discount rates for different effects	**All** life cycles are included, and discount rates are adjusted **per the criterion**
4	Trade-offs	**No** trade-offs of different alternatives are presented, without any sensitivity analysis	Scores per alternative and sensitivity are given, but the alternatives **do not** cover the wide variety of possible solutions	Adequate alternatives are considered. The scores and sensitivity are given but **only in relation to the reference scenario**	Scores and sensitivity for a wide variety of alternatives are given **absolutely and all impacts are presented**
5	Contextual input	**No** stakeholder input and no local variation of inputs	The project includes a **local priority** and has **local representation**	A dedicated public participatory process is done to **identify specific local priorities**	The participatory process is conducted, **focusing on the CBA**
6	Transparency	The CBA documentation **cannot be found,** or it is **unreadable**, **missing references** and has no explanation of the CBA methodology	The results are **published and findable** and the report is readable, but missing references and no explanation of the methodology	The results are **published**, with adequate referencing and a short explanation of the methodology	The CBA is specifically presented **in a separate meeting,** with a large explanation of the CBA methodology

5.2 Case Context

This section describes the cases. For a summary of the comparison of each case with the ideal framework, refer to appendix 11.5. For the full detailed analysis of the cases with documentation and interview results, refer to appendix 11.6.

A20 Nieuwerkerk aan de IJssel–Gouda
The project A20 Nieuwerkerk aan de IJssel–Gouda started in 2017. The project goal was to alleviate congestion. At Gouda, the road merges with the A12 motorway and crosses the river Gouwe via an aqueduct. A transformation from 2x3 lanes to 2x2 lanes at the node Nieuwerkerk causes congestion and dangerous situations further up the road. The Exploratory Study lasted until 2019. In March 2019, the Preferred Decision was published, along with the CBA. Three alternatives were considered to alleviate the congestion and compared to the reference scenario. In each alternative, the part of the motorway between node Nieuwerkerk and node Moordrecht would be widened to 2x3 lanes. The solutions for sections 2 and 3, between node Moordrecht and node Gouda, were different in each alternative. During the CBA, alternative 2 was dropped because it did not outperform the other alternatives in costs and led to an increase in traffic on provincial roads. Alternative 3 performed the best on traffic goals and was further researched, to determine the point where merging would occur.

N65 Vught–Haaren
The Exploratory Study for N65 Vught–Haaren started in 2013 after earlier regional research had been concluded. The N65 is a provincial road with a speed limit of 80 km/h. The road is used as the main route between the cities of ‘s Hertogenbosch and Tilburg but runs through the towns of Vught and Haaren. As such, there were 7 large, traffic-light-operated, intersections. The road forms a safety concern and barrier for pedestrians and cyclists. It also hinders the migration of beavers and otters. The traffic on the road causes a lot of noise and air pollution. The project focuses on liveability along and around the N65. As such, a redesign of several intersections to be separate grade and adjustment of other intersections would have to lead to improvements. In 2013, the first exploration of feasible solutions against a budget of 100 mln euros was made, of which the most viable were evaluated in 2015. The effects of different combinations were evaluated and used as input for the CBA. In the end, one of the variants scored the highest in benefits but was too expensive. A conservative version of this alternative was compared to the alternatives in the CBA. It was deemed feasible and chosen as the Preferred Decision. The Preferred Decision was signed in July 2016. Since the chosen alternative was much less ambitious than originally intended, a second opinion on the CBA was requested. That second opinion deemed that CBA was conducted accurately. The project website for this Exploratory Study has been taken offline. Copies of various documents can still be found online, but the transparency of earlier decision-making phases is insufficient. Another important factor is that there is already a national project to alleviate noise nuisance.

A67 Leenderheide–Zaarderheiken
In 2016, the Decision to Start A67 Leenderheide–Zaarderheiken was made. The A67 is an economically important east-west route from the cities of Eindhoven and Venlo to Germany. There is congestion between the nodes of Leenderheide and Zaarderheiken, mainly between exit Leenderheide and Geldrop. Alternative 1 out of three included a wide variety of Smart Mobility measures to improve traffic flow and traffic safety. Additionally, alternative 2 added a widened section between Leenderheide and Geldrop. In alternative 3, the whole section between Leenderheide and junction Asten would be widened from 2x2 to 2x3 lanes, with less attention to Smart Mobility. In the end, alternative 2 was chosen as the Preferred Decision in 2018.

A58 Eindhoven–Tilburg

The Decision to Start for A58 Eindhoven-Tilburg was published in 2013. The Exploratory Study was conducted in combination with another part of the A58, Sint Annabosch-Galder. The goal of the project organisation, Innova58, was to tender and maintain the whole track of the A58 in Brabant in one contract. In 2010, 425 mln euros was reserved for adjusting both trajectories, of which 300 mln euros was attributed to the trajectory Eindhoven-Tilburg. The economic development scenarios predicted increased congestion on both parts of the A58. The travel time during rush hour would be 1.5 times longer than outside of rush hour, which was not in line with national policy. The Decision to Start specifies the project goals, which concisely focus on legal limits for external effects, travel time savings and the budget. Two alternatives were considered: widening the 2x2 lane highway to 2x3 lanes or adding rush hour lanes. The alternative with widening had a better Cost-benefit ratio and was chosen as the Preferred Decision.

A27/A12 Ring Utrecht

The Decision to Start for A27/A12 Ring Utrecht is from 2008. The A12/A27/A28 form the southern and eastern parts of the network of highways surrounding Utrecht. The A27, connecting the A12 and A28, runs north through an open tunnel and cuts through the recreational area of Amelisweerd. In the early phases of the Exploratory Study, it became clear that widening the A27 would provide the most cost-effective solution, as opposed to constructing new highways to the west of Utrecht. The open tunnel limits the number of lanes available to traffic. In the Exploratory Study, the main solution became to separate traffic flows to improve safety and alleviate congestion. The main issue was how many extra lanes could be fitted in the open tunnel of the A27. In the current tunnel, 2x6 lanes would not be safe and the desired solution was 2x7. It was decided that the tunnel would be widened. In 2010, the Preferred Decision was finalised. No CBA was conducted since it was not mandatory at the time. After a political recommendation, the decision was made to still perform a CBA. The Ministry evaluated two variants of the Preferred Track in a CBA. The only difference between these variants is the design of node Rijnsweerd. Decisio published this CBA in 2014. The results were that in the scenario with low economic growth, the benefits would not outweigh the costs. In the high economic scenario, the benefits would outweigh the costs. As such the project advanced to the plan detailing phase with the Preferred Decision from the earlier phase, with the CBA as a legitimate source.

A7/A8 Amsterdam - Hoorn

There is congestion on the roads to the North of Amsterdam. The A8 leads from the North of Amsterdam to Zaanstad, from which the A7 routes traffic to Purmerend and Hoorn. The congestion is caused by a large portion of citizens living in surrounding towns but commuting to Amsterdam. Six different sets of measures were considered, ranging from quick wins, public transport improvements, and low-cost solutions to maximum widening of both highways, including major redesigns of node Zaandam. The CBA was conducted for combinations of individual measures. In the end, the opening of extra available lanes in the Coentunnel would lead to the highest benefit. Alternative 3, with quick wins and mobility management as well as widening at specific questions, had the highest benefits and low costs. The conclusions of the CBA report do not report a preference for one alternative, but a list of different important findings. In the end, this package was part of the Preferred Decision, but the redesign of node Zaandam and the widening of A7 north of Zaandam were also included. An important aspect was the inclusion of mobility measures, similar to the A67. This included public transport measures, but also longer-term strategies for lowering car usage. These packages were translated to input data for the traffic model, with large effects on liveability and sustainability impacts.

A2 Deil - Vught

The Decision to Start for A2 Deil - Vught was made in June 2018. The problem was congestion on the entire track, concentrated around several nodes and bridges. Another problem is suboptimal road safety, causing several accidents. After analysing and selecting possible solutions, four alternatives were considered in the CBA. The four alternatives differ in the widening of different sections of the highway, as well as the specific design of problematic nodes. The CBA was completed in June 2021. All alternatives scored a negative cost-benefit ratio in the low growth scenario, while the alternatives including widening had a positive Cost-Benefit ratio. The final Preferred Decision contained widening the road to 2x4 lanes, construction of new bridges across the Maas and Waal rivers, changing nodes Deil and Waardenburg and a large mobility package for the region.

N35 Nijverdal - Wierden

The N35 Nijverdal Wierden is an 80 km/h, 2x1 lanes provincial road connecting the cities of Zwolle and Almelo, after which it turns into the A35 highway and runs onto Enschede. The Decision to Start was signed in 2011, due to the importance of the road for the regional economy, but mostly because of the high number of accidents on the road. Two main alternatives were considered, both concerning widened N35 to 2x2 lanes with a maximum speed of 100 km/h. The first North alternative would take the N35 along the railway track, while the South variant would keep the N35s original route. Both alternatives were considered with level and grade-separated intersections. A drinking water-sourcing location caused problems, but a participatory process resulted in landowners exchanging their land so that the drinking water-sourcing location could be moved. Both alternatives with different junction designs were taken up into the CBA and all had positive CBA ratios in low and high economic growth scenarios. The resulting Preferred Decision was the Northern track with grade-separated crossings, where the local municipalities would contribute the extra 23 mln euros necessary to construct these. The original budget was 100 mln euros. The Preferred Decision was sent to parliament in March 2015.

5.3 Case Patterns & Potential Improvements

The results for all indicators from the ideal framework for all cases are given in Table 6. Scores have been marked with colours to indicate performance. For each criterion, the patterns and differences between the cases will be elaborated on. The average project score for CBAs in the Netherlands can be seen in the right column of Table 6. These scores are based on the average, rounded-off scores. This was done to limit the influence of one bad-performing case on the overall score of the Dutch CBA practices.

The comparison of the results to the ideal framework was used to derive suggestions for improvements. The improvements are focused on those criteria for which the CBA practice in the Netherlands severely underperforms and on those criteria for which the ideal framework contains best practices that are implementable, with a focus on practicality. In total 29 recommendations were derived from the results.

Table 6: Overview of ideal framework scoring for CBA in the Netherlands

Criterion	A20	N65	A67	A58	A27	A7/A8	A2	N35	CBA in the Netherlands
Boundary orientation	Insufficient	Sufficient	Sufficient	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient
Travel time benefits and reliability benefits	Sustainable	Sufficient	Sufficient	Sufficient	Sustainable	Sufficient	Sustainable	Sufficient	Sufficient
Infrastructure costs	Sufficient	Sufficient	Sufficient	Sustainable	Sustainable	Sufficient	Sufficient	Sufficient	Sufficient
Accident/safety cost saving	Sufficient	Sufficient	Sufficient	Sustainable	Sustainable	Insufficient	Sustainable	Sustainable	Sufficient
Vehicle costs	Sufficient	Sufficient	Sufficient	Sufficient	Sufficient	Sufficient	Sufficient	Sufficient	Sufficient
Wider economic impacts	Inadequate	Inadequate	Sufficient	Sufficient	Sufficient	Sufficient	Sufficient	Inadequate	Insufficient
Energy consumption	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	Inadequate	Insufficient
Resource use (Abiotic depletion)	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	Sufficient	Inadequate	Insufficient
CO2 emissions (Global Warming Potential)	Sufficient	Sufficient	Sufficient	Sufficient	Sufficient	Sufficient	Sustainable	Inadequate	Sufficient
Habitat fragmentation and negative effects on species	Insufficient	Inadequate	Inadequate	Insufficient	Insufficient	Insufficient	Insufficient	Inadequate	Insufficient
Air pollution (acidification & health)	Sufficient	Sufficient	Sufficient	Sufficient	Sufficient	Sufficient	Insufficient	Inadequate	Sufficient
Noise pollution	Sufficient	Sustainable	Sufficient	Sufficient	Insufficient	Sustainable	Insufficient	Sufficient	Sufficient
Landscape degradation has negative impacts (visually)	Inadequate	Sufficient	Insufficient	Inadequate	Insufficient	Insufficient	Insufficient	Inadequate	Insufficient

Criterion	A20	N65	A67	A58	A27	A7/A8	A2	N35	CBA in the Netherlands
Community disruption (accessibility)	Inadequate	Sustainable	Inadequate	Insufficient	Insufficient	Inadequate	Insufficient	Inadequate	Insufficient
Impacts on businesses and community services	Inadequate	Insufficient	Inadequate	Sufficient	Insufficient	Inadequate	Insufficient	Inadequate	Insufficient
Distributive effects of the project	Inadequate	Sustainable	Inadequate	Inadequate	Inadequate	Insufficient	Inadequate	Inadequate	Insufficient
Occupational and community health and safety	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate	Inadequate
Cultural heritage	Insufficient	Insufficient	Inadequate	Insufficient	Insufficient	Insufficient	Insufficient	Inadequate	Insufficient
Cradle-to-cradle life cycle thinking for all project materials	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	Sufficient	Insufficient	Insufficient
Lower/different discount rates for environmental effects	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient	Sustainable	Inadequate	Insufficient
Rigorous trade-offs: present relative weights of costs and benefits	Sufficient	Insufficient	Sufficient	Insufficient	Inadequate	Sufficient	Sufficient	Insufficient	Insufficient
Stakeholder Involvement	Sufficient	Sufficient	Insufficient	Insufficient	Inadequate	Insufficient	Sufficient	Insufficient	Insufficient
Local variation of weights and priorities	Inadequate	Sufficient	Insufficient	Inadequate	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient
Presentation of results to the public	Insufficient	Insufficient	Sufficient	Sufficient	Insufficient	Insufficient	Insufficient	Insufficient	Insufficient
Explanation of methodology, uncertainty and choices	Insufficient	Insufficient	Insufficient	Sufficient	Sufficient	Sufficient	Sufficient	Inadequate	Insufficient

5.3.1 Cost-Benefit Analysis in the Netherlands

CBA practice in motorway appraisal projects in the Netherlands performs poorly compared to the ideal framework for CBA as a sustainability assessment tool. Since the notion of sustainability is not embedded within the practice in the form of boundary conditions, it is not surprising that all projects perform insufficiently. Legal limitations for pollution and a maximum budget are always present, but further limitations for impact assessment and a variety of alternatives are not present. Regarding a full approach towards the three pillars of sustainability, Dutch CBA does not perform in line with the ideal framework. In more recent projects, a definite improvement in the estimation of reliability benefits and CO2 valuations can be seen. Noise and air pollution estimations are well embedded through model-based calculations, but other environmental impacts are poorly represented in the CBA results. Social impacts rarely make it into the CBA results, even qualitatively, unless they are specifically part of the problem analysis of the project. For strategic sustainability thinking, Dutch CBA practices are insufficient. The practitioners almost always focus on the use and investment phases and neglect the cradle or end-of-life life cycle phases. Improvement can be seen in the more recent CBA projects. Despite the national guidelines for differing discount rates, only one project transparently used different discount rates. These national guidelines for discount rates have changed during the period in which the cases took place, and the most recent addition is less focused on different discount rates for external effects. Regarding trade-offs, the Dutch CBA practice generally performs sufficiently. Risk and variation analyses are prevalent, but in the A27 and A58 cases, only a limited number of alternatives were evaluated. In all cases, the results are compared to the reference scenario, without specifying how large the effects in this autonomous reference scenario are. The relativity of the impacts as a result of the projects can therefore not be derived from the CBA reports. Regarding contextual input and transparency, Dutch CBA practice performs insufficiently. There is attention to the local variation of priorities and representation of powerful local stakeholders in the Exploratory Study. However, this influence is usually focused on identifying solutions and interests, and not on representation in the CBA itself. The reports are generally well written, even though there are issues with referencing and explaining the choices made. Little attention is given to public deliberation and explanation of the CBA results and the methodology.

5.3.2 Boundary Orientation

All the cases set boundary conditions, but most of these do not derive from a clear sustainability framework. They cannot be deemed sufficient for CBA's use as a sustainability assessment tool. The boundary conditions include project goals, such as alleviating congestion or improving safety, within a set budget and respecting applicable legal limitations. Some cases such as the A2 Deil - Vught do include WHO norms for air pollution, but these are not used in the CBA. Most cases also include warning signs for negative external nitrogen emissions, but these are not assessed in the CBA. The only two exceptions are the N65, which included clear liveability boundary settings and the A67, which included boundary conditions that focused on the inclusion of Smart Mobility measures. All cases use the same future scenarios of the PBL and associated growth of mobility but do not present the changes of the reference scenario compared to the base situation. This makes it hard to evaluate the relative effect of the project alternatives.

The main differences between the CBA practice in the Netherlands with the ideal framework yield the following possible improvements:

1. *Include a wide variety of effects in the problem analysis, not just congestion and safety improvements. Describe the development for all effects in the reference scenario to avoid missing potential added benefits.*

This improvement would make the CBA practitioners aware that an integral ambition regarding the transport problem is necessary for motorway appraisal. The trade-offs between project alternatives and the reference situation throughout the analysis period must be made clear. The assumed autonomous growth of traffic does not only cause congestion but also has negative external effects, such as noise and air pollution, that the project could and most of the time fails to address.

2. *Include stricter limits for external effects other than the legal limitations such as WHO norms, to make the information available to the public.*

This improvement is aimed at enlarging the number of boundary conditions in the CBA practice for what is deemed sustainable. The boundaries for when something is considered an impact should be evaluated according to international standards, and not the Dutch legal limitations for noise and air pollution.

3. *Include a wide variety of alternatives, ranging from few infrastructure measures to large infrastructure measures. Do not pre-emptively denounce alternatives without the help of a quick scan CBA.*

In two out of eight cases, the number and scope of the alternatives were limited because earlier appraisal phases had excluded other alternatives. From the ideal framework, as well as the interviews follows that the CBA can provide useful insights in earlier phases of the Exploratory Study to identify efficient solutions. A quick-scan CBA should be part of this.

5.3.3 Economic Sustainability

Infrastructure costs

The research has some limitations regarding the assessment of the calculation of infrastructure costs in the eight cases. This is because the CBA reports do not contain detailed information on the calculation of investment costs. They generally describe the direct investment and maintenance costs for each of the alternatives. From the interviews, some information could be gathered on what is included in these calculations. It at least includes necessary materials, salary costs, construction equipment, archaeological research, land acquisition and as can be seen from case A58, compensatory measures to reduce nuisance for road users during construction. Several interviewees indicated that the costs also contain several risk posts to account for variation. However, these costs are not publicly described since the actual purchases are yet to be made. The costs of maintenance are approximated with material, construction, and salary costs. It is also possible that compensatory budgets for noise and air pollution, as well as nature compensation, are included. However, the cases do not provide enough data to establish this with certainty. Since the investment costs are important posts in an economic feasibility tool, this research concludes that the infrastructure costs are calculated sufficiently for sustainability assessment. One other important concern for sustainability is whether the end-of-life or residual value is considered in the calculations. This does not play a role in Dutch CBA practice, since the costs are discounted. Often, a complete replacement of the infrastructure is included after 100 years, but because those costs are discounted, they are not a large item on the CBA calculation. The CBA practices can be improved:

4. *Include end-of-life valuations, demolition, and replacement of new infrastructure in infrastructure costs*

This improvement makes CBA practitioners aware of the long-term effects of high infrastructure measures for future generations. The inclusion of end-of-life valuations is an important concern in life cycle thinking and is aimed at stimulating circular design options.

Wider/Indirect Economic Impacts

Wider economic impacts are often named in the problem analyses of cases, especially the A7/A8 Corridor Amsterdam Hoorn. In two of the three CBAs conducted by RIGO, no indirect economic impacts are expected. Interviewee 2 shed light on the reasons for this practice: the projects do not result in any significant changes in economic markets. In principle, the travel time benefits cover the economic gains that should trickle down into other markets. In the cases researched by Decisio however, the Wider Economic Impacts are estimated based on a bandwidth of 0 to 30 per cent of the travel time benefits. In all their cases, the benefits are estimated at 15 per cent, even though the A7/A8 Amsterdam Hoorn is the only study with a detailed economic analysis underpinning this assumption. For the other studies, the reasoning is less clear. In the A2 project, the same bandwidth of 0-30 per cent is mentioned, but the chosen value is 5 per cent. Interviews 3 and 5 explain this choice: the A2 road already exists and no significant changes in the region's economy are expected. Through expert judgement, a value of 5 per cent was chosen. The benefits from this criterion can be significant, and the reasoning behind the choices seems arbitrary. A more detailed methodology should be developed to assess the Wider Economic Impacts. However, the current method is established, quantified, and monetised, so its inclusion in the CBA and sustainability assessment is sufficient. A potential improvement is therefore to:

5. *Standardize the requirements for attributing a percentage of wider economic benefits. Clearly indicate when a value of 0 to 30 per cent can be attributed. This method should be transparent and traceable*

Accident/safety cost saving

The valuation of accident prevention or safety benefits differs across the cases. A well-established methodology is to multiply the number of vehicle kilometres with a general calculation number that covers the probability of accidents occurring and the resulting material and health damage. However, more detailed methods are also used, which include the estimation of the probability of accidents, including the severity of the injury, based on road type and vehicle intensity. This method is more suitable for sustainability assessment. In most CBAs, the road safety studies do not cover the entire CBA project area, but only the smaller EIA study area. As such a combination of both methods for each study area is deemed the most suitable for sustainability assessment. The following improvement is suggested to create consistency in the valuation of safety benefits across CBA practice:

6. *Estimate safety effects for the study area as detailed as possible, with avoided accidents per injury category. Include a valuation based on vehicle kilometres for the larger study area,*

Travel Time Benefits & Reliability Benefits

All the cases score well on this criterion. The calculation of travel time benefits is implemented well in the Netherlands, through several national and regional traffic models. These models calculate the congestion and lost travel time and can automatically determine the travel time benefits with the Value of Time per trip category and modality as input. In the period the CBAs were executed, a change in the valuation of the reliability benefits can be observed. Instead of taking 25 per cent of the travel time benefits, a more deterministic and detailed approach is taken. In these cases, the Value of Reliability is multiplied by the standard deviation of the trip time. In the new version of the Dutch traffic models, this calculation is completed in the traffic model itself. According to Interview 3, the numbers of these calculations generally approach 25 per cent. The original 25 per cent was based on an early 2000s study by the KiM. The new approach is more specific and therefore more suitable for sustainability assessment. In general, this research deems the calculation of travel time benefits and reliability benefits suitable to be used in sustainability assessment. Similar to the safety benefits and the wider economic benefits, the following improvement is meant to improve the traceability and detail in the CBA practices, where model-based assessment replaces standardized informed assumptions:

7. *Estimate reliability benefits using the Value of Reliability and travel time variability, instead of choosing a post of 25 per cent of travel time benefits.*

Vehicle Costs

Vehicle costs are another criterion that is calculated based on the outcomes of the simulations of the national and regional traffic models. The projects in the CBAs change the route length and gradient of the road and therefore influence fuel consumption. This methodology is well-established and deemed suitable for sustainability assessment.

5.3.4 Environmental Sustainability

Energy Consumption

In some more recent EIAs, an assessment of energy consumption for the alternatives is made on a rudimentary level. No CBA report however mentions the energy consumption of the alternatives as a relevant effect. Interviewees have indicated that energy consumption during construction and operation is included in the investment costs. However, this only covers the economic component of the effect, not the external effects associated with more energy consumption. In the supply and demand energy market, sustainable forms of energy do not outcompete traditional forms of energy. That begs the question whether the market prices used for calculating the energy consumption in the investment costs adequately cover the external effects of the use of fossil fuels. The research finds the current inclusion of energy consumption in the investment costs insufficient for sustainability assessment. The following change would improve the inclusion of energy use in the CBA results.

8. *Estimate energy usage overall life cycles of the project, with a focus on the proportion of renewable and traditional energy sources, to indicate the external effects of this energy production*

The energy use is now estimated in the investment costs, presumably against market prices, and not for all life cycles. The external effects of electricity production should be considered in the CBA methodology.

Resource use (Abiotic depletion)

For this criterion, the same analysis can be made as was made for energy consumption. On a rudimentary level, it is included in the EIAs, but no CBA report mentions it separately as a relevant effect. Again, the practitioners state that the materials are included in the investment costs, but this only covers the economic effect. An added factor for the abiotic depletion of resources is not added and the external effects from mining construction materials are not included either. If resource use will be estimated with the investment costs, the life cycle impacts of said resource use should be included in the calculations for air pollution and CO2 emissions. This research deems the use of this methodology insufficient for sustainability assessment. The following improvement would include the external effects associated with raw material extraction, such as mining activity, as well as the depletion of exhaustible resources for future generations.

9. *Include a quantitative estimation of the raw materials used throughout the project's life cycle. Include multiplying factors for scarce, non-renewable materials.*

CO2 emissions (Global Warming Potential)

CO2 emissions are a well-established part of CBAs in Exploratory Studies. In every case, except for the N35, a valuation of CO2 emissions is included. This is based on a multiplication of increased vehicle kilometres with a calculation number for the price of CO2 per tonne. This price is often based on the ETS-price of the EU. The cases from the first half of the 2010s generally have lower CO2 prices per tonne than those from more recent years. In the most recent projects, the CO2-emission price goes up quickly towards

2050, to account for policy-making goals to alleviate climate change. The CO2 emissions are seldom calculated for other aspects of the projects. In the A2 case, the CO2 emissions were determined for the construction and production of raw materials, using the DuboCalc tool. This generated significant extra CO2 emissions, which in combination with a rising CO2 price contributed to the decision for a non-maximum widening of the A2 as the Preferred Decision. In most cases, the vehicle kilometres that result from the project are caused by induced demand, since the growth of vehicle kilometres in the reference scenario is considered autonomous and therefore unpreventable. Since the project effects are always shown in relation to the reference scenario, this problem is difficult to observe when reading the reports. The methodology used in the more recent CBA reports, as well as the inclusion of life cycle impacts, is key for sustainability assessment. This version of CBA practice is suitable for sustainability assessment; therefore, the next potential improvement is:

10. *Calculate the CO2 emissions from cradle to grave, including the production of materials, construction, usage, and end-of-life. Use rising CO2 price per tonne.*

Habitat fragmentation and negative effects on species

All cases mention that the alternatives could have negative effects on nature and specifically Natura2000 areas. This is often analysed as part of the EIA and is not transferred into the CBA report. No compensatory effects are budgeted in, even though the interviewees explain that the acquisition of nitrogen emission rights could become part of the land acquisition post in the investment costs. The valuation techniques for the ecological and recreational value of nature are not used. In the A27, with a specific focus on the recreational nature area Amelisweerd, the ecological value of tree replacement was considered, even though it was a relatively small post on the final Cost-benefit ratio. Decisio explicitly mentioned that this valuation technique, based on compensation for ecological services, does not cover the recreational and landscape value of Amelisweerd, in its current location, close to the city. In response to a suggestion to use the valuation techniques released in the CBA Guideline Nature of 2018, the interviewee responded that those methods would not have applied to Amelisweerd. Generally, the CBA reports should show more of the effects on nitrogen-sensitive areas, either qualitatively or quantitively in nitrogen deposition values, to show the inclusion of the effect and the clear decision not to value it. At the same time, a specific CBA methodology should be developed for the valuation of compensatory measures. Right now, the CBA practices for these impacts are not sufficient for sustainability assessment. An improvement would be to:

11. *Estimate and provide the quantitative values for effects on nature and protected species. Include the costs for compensation or the cost of avoiding effects.*

This improvement would properly include the importance of protected species and nature for ecological value. The cost for compensation of ecological nature areas is an easy-to-use valuation that should be implementable.

Air & Noise Pollution

Air pollution is a large part of the Dutch CBA practice, at least in the operational phase. In most cases, except for the N35 and the A2, air pollution is calculated by multiplying the increase of vehicle kilometres with a calculation number for the damage caused by several pollutants. In most CBAs executed by RIGO, the calculation number is generalised for all types of pollutants, while the CBAs conducted by Decisio generally contain a specification into different categories of pollutants. In addition to the general method, most EIAs assess the air pollution on affected people and categorize them into pollution classes. These pollution classes can also be used for a CBA valuation of air pollution, in the direct study area of the EIA. Outside of this study area, the general vehicle kilometre-based method is often used. In the A2 case, the air pollution assessment included norms from the WHO, in addition to Dutch legal norms. However, since the

number of significantly affected persons was lower than 5 per cent of the total affected households, no calculation was made for the EIA, and it was also not included in the CBA. The Netherlands Commission for Environmental Assessment (CommissieMER) and several Views have indicated a preference for a valuation based on the number of lost QALYs or DALYs, but the interviewees stated that they do not consider this a valid CBA method. Until such a method exists, the method of separately assessing the air pollution for directly affected households and the general affected area outside of the EIA study area is sufficient for sustainability assessment. Noise pollution is calculated in the same way as air pollution, by multiplying standardized calculation numbers for comfort and health costs of noise pollution with an increase in vehicle kilometres. Similarly, the EIA also requires an affected household analysis, which can be used as input for the CBA. Often though, the damage classes start at much higher dB values than what the WHO recommends as healthy living standards. It is also unclear whether the assessment of comfort accurately represents the value decrease most citizens are concerned about when it comes to higher noise emissions. In addition, the noise emissions are only calculated in relation to the reference scenario. This means the noise pollution of the autonomous growth of vehicles is not considered. The level of detail of the assessment of air and noise pollution is sufficient when both directly affected households and the general increase through vehicle kilometres are separately considered. As such, a recommendation would be to:

12. *Estimate noise and air pollution at the household level during the use level, taking the WHO values as a base level. If household-level analyses are not available in the wider study area, use the general vehicle kilometres methodology.*

The next improvement focuses on the inclusion of life cycle thinking when estimating air and noise pollution. This would warrant a specific focus on the noise and air pollution of construction periods, which can take multiple years. Construction projects can take up many years, and while compensatory measures for road users are included in the investment costs, the effects of the construction on residents are not considered. Consequently, an improvement would be to:

13. *Estimate the nuisance to residents in terms of air and noise pollution during the construction of the project.*

The last improvement to the practices would honour the request of the Netherlands Commission for Environmental Assessment to value air and noise pollution based on QALYs instead of using exposure classes, which is similar to an argument made by citizens in the A2 case.

14. *Create a CBA standard methodology to value air and noise pollution in QALYs or DALYs*

<u>Negative visual effects of landscape degradation</u>

The spatial quality and loss of landscape are not considered quantitatively in the CBA reports of the cases, except for the N65. In that case, visual quality effects are determined, though mostly qualitative. The decrease in property value is monetised by estimating the monetary value of having a free view, which would be obstructed in the N65 case. Other projects only mention the effect qualitatively or fail to mention it at all. It should be mentioned that in most cases when a road is widened, the road does not require additional space, and thus the effect on spatial quality is limited. However, the methodology used in these cases is insufficient for assessing landscape degradation. An improvement would be to:

15. *Estimate the effects of a decrease in spatial quality. If the effect can be isolated to the effect of having a free view or property on the water, monetise using hedonic analysis.*

Motorways can have a large negative effect on the visual quality of an area, and this effect should be included in the CBA for sustainability assessment.

5.3.5 Social Sustainability

Community disruption (accessibility)

Local accessibility is part of the travel time benefits in all cases. This social criterion deals with the cross-ability of a road and the accessibility effects associated with that. Only in the N65, this value was monetised using travel time benefits for cyclists. This estimated the cross-ability effect of the new separate-grade intersections. In most other cases, cross-ability does not play a large role in the projects, since the road already forms a barrier in the first place. However, almost all CBAs fail to mention the effect in the first place. In the A2 project, some positive effects were considered, since one of the alternatives contained a new crossing for the river Maas. However, these effects were only described qualitatively. The CBA practice cannot be considered sufficient for sustainability assessment.

16. *Estimate effects on the cross-ability of a road qualitatively, if possible, monetise with travel time benefits.*

This recommendation focuses on trying to incorporate the barrier a motorway forms into a monetizable term, with potential undervaluation. In the N65, cross-ability was used as a proxy for this value.

Impacts on businesses and community services

The CBAs generally do not contain information on impacts on businesses and community services. From the interviews was derived that the costs for land acquisition are covered under the investment costs. These acquisition costs include compensation for the economic value of the land. For sustainability assessment, it is necessary to at least mention, qualitatively, the losses of economic and community services, as was done with the A2 project. An improvement would be to mention the effects on businesses and community services in the CBA report. By mistake, this improvement was not inquired after in the feasibility study, which is why it is not numbered in this section.

Distributive effects of the project

In most cases, the distributive effects are not explicitly shown, even though all interviewees state that it's common to make analyses for stakeholder groups if the problem analysis asks for it. Decisio mentions in all its CBA reports that CBAs can indicate the distribution of effects but does not follow up on this notion. Intragenerational distributions are not shown. The current practices are not sufficient for sustainability assessment. An improvement would be to provide the public with information regarding the division of costs and benefits across parties. The CBA is done from a societal, and national perspective, but the equity of effects is also relevant:

17. *Always provide a figure describing the distribution of costs and benefits across different stakeholder groups, such as national versus local governments, users versus residents and different generations.*

Occupational and community health and safety

No CBA shows the effects of labour conditions of production materials or nuisance caused to residents during the construction of the project. This is insufficient for sustainability assessment. The interviewees mention that the investment costs can include reserves for the acquisition of sustainable materials. This should be mentioned in the CBA. The following improvement is focused on assessing the influence of Dutch motorway projects on the labour conditions in other countries, which is part of assessing the effects across the entire supply chain. The improvement would make Dutch decision-makers take responsibility for making socially unsustainable decisions.

18. *Include an estimate of the number of products/materials originating from places with worse labour conditions than the Netherlands.*

Cultural Heritage

Only some CBAs, such as the A2, qualitatively mention the loss of cultural heritage and cultural landscape because of the project alternatives. This should be standard practice for sustainability assessment. A general methodology for the valuation of a hectare should be developed. The interviewees explained that costs for archaeological research are covered in the investment costs. An improvement would be to focus on the large impact that motorway projects can have on land areas that are of significant cultural value. In the CBA literature, valuation methods are mentioned, of which the travel cost method is one. Dutch CBA practice should:

19. *Develop a standard methodology for the valuation of culturally significant land. Consider valuing recreational value through revealed preference methods such as the travel cost method.*

5.3.6 Strategic Sustainability Thinking

Cradle-to-cradle life cycle thinking for all project materials

The Dutch CBAs generally do not include more than two life cycles in their assessment of the project alternatives. The focus is on the start year of the operation and the investment costs. Except for the A2 case, no analyses are made to assess impacts on the production of raw materials. In the project A2, this is only done for CO2 emissions and not for other pollution. The end-of-life should be a part of these life cycle calculations as well. The largest improvement would be to:

20. *Include all life cycles from cradle to grave for as many objects as possible in the alternatives, mainly the raw material production*

Lower/different discount rates for environmental effects

The prescribed discount rates have changed once in the sample of cases that were researched, in 2015. In this document, the guideline was to value the sunken costs (e.g., investment costs) with a relatively low discount rate and large non-linear benefits (e.g., congestion benefits) with relatively high benefits, instead of the same rate. At the same time, another guideline was to value external effects with lower discount rates. While most cases adopted a lower discount rate than before (5.5 to 4.5 per cent), little information is given in the CBA reports on these guidelines. The exception is the set of discount rates used in the case A2, which corresponded to the prescribed rates. In the new report from the Werkgroep Discontovoet (Rijksoverheid, 2020), the discount rates have been updated and lowered again. The numbers for external effects remain the same. The discount rates in Dutch CBAs need to be adjusted per criterion to be considered sufficient for sustainability assessment.

21. *Include lower discount rates for external effects such as CO2 emissions, air and noise pollution and sunken costs than for benefits*

5.3.7 Rigorous trade-offs

Generally, the CBA reports present the effects of different alternatives adequately in large tables, including sensitivity analyses. However, they are always presented in relation to the reference scenario which negates the large negative influence of the autonomous growth of traffic. In the problem analysis, the only problem that is associated with the reference scenario is the congestion caused, while the estimated growth of vehicles has negative effects on noise and air pollution as well. A more integral approach to the reference scenario would be more transparent than the current practice. It would also open the door for mitigation if the costs for mitigation outweigh the negative benefits of external effects. One interviewee mentioned that

presenting the reference scenario would be wrong since it would pose the policy question whether the reasons [population growth and economic growth] for mobility growth are desirable. Another interviewee indicated that it would be good to always include the reference scenario to see the relative size of the effects.

22. *Show the effects of the reference scenario, be it in a separate table, to indicate the relativity of the project's effects.*

This improvement would show the relative effects of the project alternatives and indicate which problems they solve and which they do not. For this the relative size of the effects compared to the autonomous development of mobility.

5.3.8 Contextual input

Local variation of weights and priorities

The CBA reports do not mention this criterion. The interviews however provide that the problem analysis often includes local problems in addition to the national project goals. Examples of this include the A27/A12, with a focus on Amelisweerd and the N65, which focused on the liveability of neighbouring villages. In the case A7/A8, the focus was put on estimating the effects on the regional economy, even though few of the results are shown in the CBA. The CBA practice needs to improve to be sufficient for sustainability assessment. An improvement would be to:

23. *Include a specific list of local interests that were addressed in the CBA, to inform interested stakeholders on whether the CBA covers the interests they find important.*

Stakeholder Involvement

The CBAs do not mention anything about stakeholder involvement in the CBA itself, although participatory processes are held in the Exploratory Study to gather information on local problems, solutions and important. When local governments take part in combined client organisations, stakeholders are more involved in the CBA and its results, such as was the case with the A7/A8, N65 and A58. There is no direct participation to gather input for the CBA. This is not sufficient for the use of a sustainability assessment tool in a democratic society. An improvement would be to:

24. *Pay specific attention to the CBA in public stakeholder meetings and gather input for which effects to focus on. Do not only consult powerful stakeholders.*

This recommendation is aimed at specifically involving those stakeholders that want to participate in the CBA methodology process, through a bottom-up approach.

5.3.9 Transparency

Explanation of methodology, uncertainty, and choices & presentation of the results

Most of the CBAs contain a basic explanation of what the CBA methodology is and how it works. The level of detail of these explanations differs across the cases. Some firms put the calculation numbers in the main report, while others only include them in an appendix. From a readability point of view, it seems best to include them where they are most relevant; near the effect, where they are used. A problem with the current practice is that there is no standard list of effects that should generally be considered in the CBA, which makes the reader wonder whether effects are not included because no effects are expected, or they have been left out for political reasons. In most cases, the qualitative results of the EIA are not transferred into the CBA, but a positive trend is noticed in more recent CBAs. Some of the documentation is hard to find since the project websites have been taken offline. Additional research and inquiry were necessary to find the documentation related to the cases. The inclusion of CBA ratios in the policy documents on the

Preferred Decision, such as the structure vision, is not consistent in the cases. The level of detail in the summaries of the CBA reports is limited. The CBA is often only an appendix to the other Exploratory Study documents and therefore is not presented separately and explained by the practitioners of the CBA. This is usually done for the client and important stakeholders. The analysis results in the following improvements:

25. *Include a standard list of effects which are common to addressed in CBAs for infrastructure projects. Be transparent and mention effects for which no effects are expected.*

This recommendation is focused on improving the transparency and consistency of CBA practice, to show readers what effects have been considered and that if no impacts are expected, this is explained.

26. *Create a central database containing all CBAs conducted in Dutch infrastructure projects, with links to the Exploratory Study to improve transparency on the changes in Dutch CBA practice*

This recommendation stems from the difficulties the researcher had to find CBAs and Exploratory Study documentation for projects for which the project website had been shut down. It would be fruitful to have an overview of CBAs, for CBA practitioners to learn from each other's experiences and to be aware of changes in the field.

27. *Include calculation numbers where they are most relevant, near the effects they are used for.*

This recommendation stems from the researchers' experience with the readability of documents and that if you want to follow and compare CBA results, it is consistent to not have to scroll through appendices, but see the numbers where they are most relevant, with some explanation of what the calculation number entails.

28. *Organise at least one public CBA meeting in which the CBA results are explained by those who conducted the analysis.*

In most cases, the CBA was not presented to the public in paper form but only published by the Ministry. This improvement would put more focus on the CBA as a decision-making tool. The next recommendation is focused on the actual presentation of the CBA results and therefore transparent inclusion of the results in the decision-making process since the differences between the cases are large.

29. *Describe the outcomes of the CBA, with at least the table summarizing all effects in the EIA and the Preferred Decision to be transparent.*

6. Feasibility

This section contains the results of the expert survey and their implications for the feasibility of the potential improvements. The 29 suggested improvements were, based on the level of agreement and argumentation of the respondents, categorised into *feasible* improvements and *moderately feasible* improvements. A problem in the original formulation of the improvements for the expert survey was that it was unclear who was responsible for executing the improvement. This was also indicated by the respondents of the survey. In this section, considering the comments of respondents, the responsibilities of different organisations for executing the improvement have been provided.

The next section describes the feasible improvements, followed by a discussion of the moderately feasible improvements. Table 7 gives a detailed overview of the arguments provided per improvement. The results of the feasibility calculations are given in appendix 11.7.

6.1 Feasible improvements

The improvements that should be implemented immediately by the responsible parties are the following:

CBA practitioners must:

- Include end-of-life valuations for demolition or expected replacement of new infrastructure in the investment costs, as part of life cycle costing.
- Calculate CO2 emissions from cradle to grave, especially taking into account the extraction and production emissions for construction materials.
- Estimate safety benefits, noise and air pollution based on detailed studies from the EIA and use a calculation number, vehicle-kilometres-based approach for the portion of the study area that is larger than the EIA.
- Include a list of local interests that were taken into account for the CBA to provide transparent decision-making information to decision-makers and the public.
- Describe the division of costs and benefits across different stakeholder groups

The client of the project should always summarise the CBA findings in the resulting policy documents, such as the Preferred Decision or the Structure Vision. Moreover, clients should include the CBA results in public meetings, and CBA practitioners should be present to explain them. Additionally, the government and clients of motorway projects should create a central database for the publication and review of CBA reports, for the CBA community to learn and consistently present the results to the public. Another feasible recommendation is for clients and CBA practitioners to take into consideration a wide variety of different alternatives, with the help of a quick-scan CBA in the early phases of the Exploratory Study. Furthermore, Dutch policy analysis organisations and the government should include a core set of impacts that be at least should be considered in motorway appraisal projects, even though CBA practitioners should be free to add additional effects they deem relevant in their projects.

6.2 Moderately feasible improvements

The other suggested improvements are generally still feasible and should be considered to improve the performance of CBA as a sustainability assessment tool. However, various levels of additional research and clarification are necessary to make the improvements usable for CBA practice. Generally, this research should focus on practicality, required resources and valuation methods.

Relating to **boundary conditions and showing trade-offs**, more research should be done into how CBA practitioners can accurately show the development for all effects caused by the expected autonomous developments. It would indicate the relative impact of the project alternatives and show which problems the project addresses and which could be addressed, such as air and noise pollution. Additional research from the calculation number agencies, such as CE Delft, is also required, to compare Dutch calculation numbers for external effects to international standards, such as the WHO norms. Dutch calculation numbers take into account effects on comfort and health, but whether the used boundary conditions for when these effects occur differ from international standards is unknown.

Regarding **economic sustainability**, the survey indicates there is support for calculating and attributing reliability benefits and benefits from indirect economic effects more systematically and transparently. Reliability benefits should be attributed based on the Value of Reliability and the variance in average travel time and not with an estimation of 25 per cent of travel time benefits. The percentage of benefits for indirect economic benefits, ranging from 0 to 30 per cent, should at least be based on a decision-making framework,

such as a flowchart. However, which method is the best and should be used in practice should be evaluated by CBA practitioners and policy analysis organisations such as the CPB.

Regarding **environmental sustainability**, the size of the negative benefits caused by nuisance to residents during construction should be evaluated. This is now not included in the analysis, while compensatory costs for diverting road users are included in the investment costs. The respondents indicated the size of these costs is not large and does usually not differ significantly between alternatives. Furthermore, the external effects of energy usage and material extraction should be included by CBA practitioners, but a practical and proportional method should be developed by policy analysis organisations and CBA practitioners. Caution should be used when calculating CO2 prices since some market prices already include the purchase of ETS rights. It should also be evaluated whether market prices for construction materials accurately describe the scarcity of non-renewable materials for future generations.

Calculation number agencies and policy analysis organisations should evaluate whether Dutch calculation numbers for the effects of air and noise pollution could be translated to QALYs or DALYs and whether there are significant differences between both assessment methods when evaluating the impacts of noise and air pollution. Assessments of effects on culturally significant land and landscape degradation should always be included, at least on a qualitative level. The same goes for effects on nature and protected species. The respondents did provide valuable insight into the lack of proper valuation methods. Hedonic analysis and costs for compensation are not always applicable, and an undervaluation of the effect or too time and resource-consuming.

Regarding **social sustainability**, the effects of a road for community disruption should be evaluated, at least qualitatively. However, the respondents expressed that the methods for valuation of these effects are limited and often undervalue the effects that roads have on community disruption, although it must be said that the ability to cross a motorway does not change in most projects. The respondents were divided on whether and how the origin of construction materials from countries with differing labour conditions should be included and valued in CBA. A clear guideline from the government to include a reserve for the purchase of socially sustainable materials in the realisation phase is more effective than assessing this uncertain and detailed criterion.

When focusing on **strategic sustainability thinking**, Dutch CBA practitioners are divided about using different discount rates for different kinds of impacts. The Dutch guideline has changed significantly over the last ten years and more research is necessary to evaluate what trade-offs arise with the use of different discount rates to improve CBA as a sustainability assessment tool. Policy analysis organisations and CBA practitioners should also combine their efforts and expertise to devise practical and clear methods for estimating effects in different life cycle phases. Regarding **contextual input,** the respondents do not support a large role for local input in CBA reports. It is however a good practice for sustainability assessment tools, and it should be evaluated to what extent interested persons can add valuable information and purpose to the CBA practice. This should not just be seen as changing the technical analysis, but also as a moment for deliberation and explanation of a public decision-making tool. Lastly, focusing on **transparency,** a guideline should be made on where to include calculation numbers, since the opinions on what is readable for the public differ.

Table 7: Feasibility assessment per suggested improvement

Recommendations		Feasibility Assessment	Who is it applicable to?
Feasible		The results indicate these improvements are feasible and supported by CBA experts. They should and can be implemented immediately.	
23	The specific list of local interests to inform interested stakeholders.	This improvement is deemed feasible because it is supported by all respondents. The concerns focus on retaining the consistency of reporting and not changing national methodologies to assess impacts differently for local contexts. A list for information purposes is supported.	CBA practitioners, Exploratory study Consultants, clients
10	Calculate the CO2 emissions from cradle to grave, using rising CO2 price per tonne.	Almost all respondents support this improvement. They support the inclusion of more life cycles for CO2 calculations and the use of rising CO2 prices. Most comments resort to the fact that currently, used CO2 prices are already rising. Manufacturers of construction materials, at least in Europe, are covered under the ETS system and emissions resulting from production should be valued with a CO2 price of which the ETS price is subtracted.	CBA practitioners, Calculation number developers
26	Central database containing all CBAs conducted in Dutch infrastructure projects	Almost all respondents support this improvement. The few concerns focus on what would happen with a database and who needs to procure it. It would be useful to allow independent parties to evaluate CBA practice, which has happened in recent years. Another respondent indicated the use of this database for the public is not warranted, since additional explanation would be necessary to reach an improvement in transparency	Clients, government, policy analysis organisations
4	Include end-of-life valuations, demolition, and replacement in infrastructure costs	Most respondents strongly agree with the recommendation. One argument for disagreement is that projects should only be considered for their lifespan. Demolition and replacement are separate projects. Another remark mentions that costs for demolition of current infrastructure are included in current CBA practices. For sustainability assessment, it is essential to assess the end-of-life of infrastructure objectives, since it is reasonable to assume that it will have to be removed or adjusted at the end of its lifespan	CBA practitioners, cost engineers
6	Estimate safety effects with maximum detail number	All respondents agree, at least to some extent. The argument for not agreeing strongly is this should be dependent on project size and goals, along with the available time and resource budget to determine to what level of detail these can be estimated. It is also common to do in recent CBAs.	CBA practitioners
17	Describe the distribution of costs and benefits across different stakeholder groups	All respondents agree and some mention this is already standard practice if it is relevant for decision-making. Relevance is usually based on providing information to other financial contributors. In the case study research, this practice was not observed and for sustainability assessment, it is necessary to always indicate the division.	CBA practitioners, clients
3	Include varying alternatives. Do not exclude alternatives without a quick scan of CBA.	Almost all respondents agree. Respondents support the creation of multiple, significantly differing alternatives, and using a quick scan CBA in early Exploratory Study phases. They also mention this is now common. Argumentation for not fully agreeing includes that the client does not support early inclusion of the CBA since the main alternatives and solutions have already been determined.	CBA practitioners, Exploratory study consultants, clients

29	Summary of CBA results with a table in the EIA and the Preferred Decision	Most respondents support this agreement but mention the EIA is an input document for the CBA and therefore the results should not be reported back into the EIA. It should always be mentioned in the Preferred Decision or other final policy documents.	Exploratory study consultants, clients
28	Organise at least one public CBA meeting in which the CBA results are explained	Most respondents agree with this improvement. However, there are also disagreements. This meeting should be integrated into existing information meetings organised by the client. Some projects are too small for this to be mandatory. Another comment was that no one is interested in such a meeting.	Clients
25	A standard list of mandatory CBA effects	Most respondents agree with this improvement and some stress that in practice a standard 'list' is already used. Other concerns include that it is unclear who should make such a list and whether specific effects in projects would be excluded because of this. Considering more effects generally does not lead to a *better* CBA. Policy analysis organisations should develop a list and it should be stated at the start of each CBA report.	CBA practitioners, policy analysis organisations
12	Estimate noise and air pollution in maximum detail	Most respondents support this improvement. This is the best practice in CBA, which the respondents indicate is common in more recent projects. The respondents struggle with the focus on WHO values, which are not country specific. They prefer to use Dutch boundaries for damage and comfort loss. Updated calculation numbers were published recently. A comparison should be made between the Dutch calculation numbers and WHO limitations by calculation number agencies.	CBA practitioners, calculation number agencies
Moderately feasible		For these recommendations, the results of the survey indicate they are ideologically sound, but that practical considerations make them less feasible. Additional research and clarification are necessary.	
9	Quantitatively assess the amount of raw materials used throughout the project's life cycle. Include multiplying factors for scarce, non-renewable materials.	Most of the respondents support the underlying idea but disagree with the method mentioned. Concerns focus on the resources necessary to accurately estimate this and on the general uncertainty in the future. Instead, the external effects of material production should be included. Market prices already cover the scarcity of materials, through a principle known as the Hotelling rule. Double assessments should be prevented. It'd be more effective to mandate the use of sustainable materials and include that in the investment costs. The researcher finds that it is unclear whether the Hotelling rule accurately covers the loss for future generations when scarce resources are used, it is a widely criticized economic idea. The recommendation should be changed to 9a) value the external effects of raw material production, and 9b) evaluate whether scarcity of resources is covered by rising market prices and whether rising market prices are used in cost calculations practices	CBA practitioners, calculation number agencies, clients
15	Assess the effects of a decrease in spatial quality. If the effect can be isolated, monetise using hedonic analysis.	Most respondents agree that this would be useful. They agree it should be included at least on a qualitative level. They question the practical feasibility of the valuation method. If there is no real estate near the project, then conducting a hedonic analysis is not possible and how to account for the subjectivity of visual quality is difficult. These analyses are costly and take time. A framework based on earlier studies would be more suited. The recommendation is therefore changed to develop an analysis which can be used to value landscape quality in CBAs for motorway appraisal	CBA practitioners, calculation number agencies, policy analysis organisations

21	Include lower discount rates for external effects	Most respondents agree with this improvement, but some are strongly opposed. They indicate the Dutch guideline for the distinction of external effects has been removed recently. Another person remarks that differing discount rates do not make the CBA more accessible and understandable to non-professionals. None of the respondents provided a fundamental agreement and the assumption can be made they disagree based on economic principles. More research into how discount rates are determined in the Dutch guideline is necessary.	CBA practitioners, calculation number agencies, policy analysis organisations
22	Show the effects of the reference scenario, be it in a separate table, to indicate the relativity of the project effects.	Most of the respondents agree with this recommendation. Those that disagree mention that the reference cannot be changed through policy so the impacts should not be assessed. The effects should only be described in the text, and not in the table. Another argument is that some benefits cannot be calculated in the reference scenario, such as travel time benefits. The researcher argues that CBA should calculate negative benefits in the reference scenario, since the growth of mobility without physical measures would result in higher vehicle loss hours (VVU), compared to the current situation. You could calculate the total vehicle kilometres for the reference scenario and compare that to the current vehicle kilometres, relative to the alternatives and do the same for external effects where it is applicable. In a different framing, alternatives do not have benefits, they prevent negative benefits from occurring. It would therefore be interesting to not estimate effects in relation to the reference in a certain year but relate all effects to the current year.	CBA practitioners, policy analysis organisations
5	Standardize the requirements for attributing a (0-30) percentage of wider economic benefits.	Most respondents agree somewhat with this improvement. The main issue is the interpretation of the word ‘standardize’, as most respondents seem to think this would mean the creation of one standard calculation number, or a ‘rule of thumb’. Most of them stress that projects have specific situations and that a standardized methodology would not reflect these local situations appropriately. A lot of research has been done into this topic and no substantial agreement can be achieved. One of the respondents mention that in Flanders a flowchart is used to attribute a percentage.	CBA practitioners, policy analysis organisations
27	Include calculation numbers where they are most relevant, near the effects they are used for.	Only half of the respondents agree with this improvement. Most of the respondents mention this would worsen readability for the public and that an appendix for interested parties is sufficient. The research recommends what most people would find more readable. In the end, the document is part of the information supplied by the government to citizens, which should meet certain requirements.	CBA practitioners, policy analysis organisations
8	Estimate energy usage overall life cycles of the project, focus on the proportion of renewable and traditional energy sources	Most respondents agree, but there is a risk of double counting environmental benefits since new calculation numbers for energy in 2016 include differentiation between traditional and renewable energy. These are efficient prices and are connected to the rising CO2 price. Furthermore, the question is whether energy use can be estimated with certainty and whether the extra work necessary would change the results significantly. The researcher acknowledges that CO2 emissions are included inefficient energy prices, but these are for energy market projects and not infrastructure CBAs. Additionally, it is unclear whether the other external effects are included in these prices. This improvement is adjusted into 8a) that the energy used to produce materials, construction, operation, and demolition should be estimated using calculation numbers and 8b) that valuation of energy usage should use calculation numbers that include the negative external effects of energy production.	Calculation number agencies

19	A standard for the valuation of culturally significant land. Monetise recreational value with the travel cost method.	Almost all respondents agree. It should be included at least qualitatively, but the travel cost method is not always useable. Another argument is that there should not be a standardised rule of thumb, but room for specific efforts and methods.	CBA practitioners, policy analysis organisations, calculation number agencies
1	Describe the development for all effects, not just congestion and safety improvements, in the reference scenario.	Almost all the respondents agree to some extent and indicate this is already the case for most projects. However, this is only described in the text and not shown in the table. Two respondents stated that if external effects are a problem, they will be included in the problem analysis in current practices. If they are not a problem, they are not mentioned. Another respondent that disagreed stated that CBA calculates the effect of the project alternatives in relation to the reference situation in a certain year. The reference is therefore not important to illustrate these effects. Further research should indicate how this would affect the practice.	CBA practitioners, policy analysis organisations
7	Estimate reliability benefits using VoR, do not use 25 per cent of travel time benefits.	Almost all respondents agree to some extent. An argument for not strongly agreeing is whether it makes a difference in the result or whether the standardized assumption is detailed enough. The second argument for not strongly supporting the recommendation has to do with the fact that information should be present about human behaviour in relation to reliability before these benefits can be included. This is surprising, as this is currently not the case.	CBA practitioners, policy analysis organisations
20	Include all life cycles for as many objects considered in the alternatives	Many respondents agree with the idea but question the practicality of including all life cycles in the CBA for all effects. Time and resources are limited, and there is uncertainty about the future, but also regarding use. More research is necessary to determine the relative effects of different life cycle analyses.	CBA practitioners, policy analysis organisations
13	Estimate the nuisance to residents	Most respondents agreed at least partially. However, most respondents indicate this is not a relevant effect for the decision between alternatives. Mitigating measures during the construction are also included. It is unknown whether these mitigating measures also include measures to alleviate local noise and air pollution. More research into the relative size of the effects should be conducted.	Policy analysis organisations
14	Create a standard methodology to value air and noise pollution in QALYs or DALYs	Most respondents agree, but some indicate that the Dutch calculation numbers should be used instead and that health effects are covered in that. The respondents do not see a reason to switch to the provision of QALYs, since the current methods already cover those. The argumentation in favour of using QALYs is that the impact classes from the EIA do not transcend into the CBA and that QALYs are easier to understand for the public than calculation numbers. A study into the translation of health effects into QALYs for information provision should be conducted	Policy analysis organisations, calculation number agencies

16	Estimate effects on the cross-ability of a road qualitatively, if possible, monetise with travel time benefits.	Most respondents agree it should be included, at least in a qualitative way, although some stress that motorways are always a barrier and that does not change in most projects. There is uncertainty as to the specific design of intersections. The suggested monetisation would be an undervaluation of the effects, which the researcher condones. More research is necessary to accurately determine the assessment method for the effects of community disruption	Policy analysis organisations
11	Estimate effects quantitatively on nature and protected species. At least Include the costs for compensation	Most respondents agree, at least in a qualitative way. The valuation of specific species is considered useless, but quantification of nature loss can be done with the 'nature points' methodology of the CPB, but there is no valuation method associated with this. Furthermore, there is uncertainty about how much knowledge of this criterion is available and sometimes impacts are not compensable. The costs for compensation are probably an undervaluation of the real value of nature. More research is necessary into the translation of the nature points into CBA practice, and until then costs for compensation should be estimated and included.	Policy analysis organisations
24	Have participation meetings for input into the CBA	Most respondents agree to some extent, but two respondents disagreed strongly. They state that this contact is contra productive and only leads to discussions of the methodology itself. Others state the CBA should be explained in the same way that the other Exploratory Study documents are presented, with an explanation of the methodology, but not a discussion of the methodology itself. In general, people might lack the technical understanding of what a CBA is and how it works, which makes discussion difficult, and people might confuse the political nature of a decision-making process with an analytical tool such as the CBA.	Client
2	Include stricter limits for external effects other than the legal limitations such as WHO values	Initially, most respondents support this notion. However, most respondents indicate legal limitations do not apply to CBA, since it only assesses impacts. In essence, norms are not relevant. They influence the feasibility of the project legally. Whether the Dutch calculation numbers for damage are on par with international standards is unknown. More research should compare Dutch calculation numbers to the international research and norms on the damage of external effects	Calculation number agencies
18	Estimate products/materials origination from places with different labour conditions than the Netherlands.	Half of the respondents agree to a certain extent, mostly based on ideological grounds. One respondent mentions external effects of transport should also be included. However, about a third of the respondents strongly disagree. The arguments for disagreement include a general uncertainty about which construction company will be selected. Other arguments are it takes too many resources and is not informative. Another respondent mentions that the Dutch government should not lecture other countries in how they want to manage their resources. The researcher accepts that it this thorough analysis would take significant resources.	Policy analysis organisations

7. Discussion

This section discusses the findings of the research in a larger societal and scientific context. The research problem this research focused on was whether and how Cost-Benefit Analysis can be and is currently being used as a sustainability assessment tool, to prioritize sustainable alternatives in motorway appraisal projects.

An analysis of scientific literature on sustainability assessment established six criteria for sustainability assessment tools. These criteria do not only focus on the technical assessment methods used within the tool but also incorporate policy process requirements for transparency and contextual input. CBA is an economic assessment method that focuses on the economic efficiency of policy options, expressed in the Cost-benefit ratio. From the best practices of the ideal framework, it follows that CBA can to a large extent be used as a sustainability assessment tool, which is in line with the findings of Bueno et al. (2015).

Based on the findings from the literature and the case studies, CBA can be used as a sustainability assessment tool. When evaluating the full approach towards sustainability impacts, it is clear that economic assessment methods exist for the evaluation of economic and environmental impacts and to a lesser extent for social effects. Strategic sustainability thinking, meaning the inclusion of different life cycle phases and discount rates as well as the inclusion of boundary conditions and the showing of trade-offs can help prioritize sustainable alternatives. Process-related best practices can be used to ensure transparency and the inclusion of contextual input.

A main limitation of CBA is that some impacts cannot be quantified or monetised and therefore are not covered in the Cost-benefit ratio. However, at least in Dutch CBA practice, it has become common in recent years to express non-quantifiable effects, mostly effects considered in the EIA, in the CBA report and PM-posts. If the CBA report is integrally taken into account in the political decision-making process, all impacts are considered in the policy decision. However, it is unclear to what extent this nuance and level of detail of the CBA report will transcend into the decision-making process. It is more likely that a focus will remain on the less complex Cost-benefit ratio.

This means a focus on quantification and monetisation of as many impacts as possible is the right practice. Here, general issues that persist with the use of CBA are reiterated, also by experts in Dutch CBA practices. Inherent uncertainty and lack of time and financial resources are barriers when making a detailed assessment of sustainability impacts. For most economic impacts and some environmental impacts, model-based calculations have been developed and improved over time to simplify the assessment process. For most life cycle environmental and social effects, such standardized calculation numbers and tools do not exist. Exceptions can be seen in more recent projects, where CO2 emissions in the cradle life cycle phases are calculated. The potential improvements that have been suggested all experience the same issue that no standardized methodology exists yet, and further research to develop these methods is necessary. The roots of CBA in welfare economics form an additional barrier to new quantification and valuation methods. While most CBA experts agree that impacts occur, insulating them to a welfare effect, without double counting, is often difficult, which makes CBA practitioners wary of implementing them as they could present an under- or overvaluation. As such, the choice is often made to not include the effects in the CBA report.

Furthermore, the findings of this research focus on how CBA can be used to assess sustainability impacts, but not to what extent this assessment would improve the prioritization of sustainable alternatives. A main issue for sustainability is that the alternatives considered need to be defined from a sustainability perspective in the first place. One interviewee expressed that if we want to assess sustainability, we have to design for sustainability (Interview 1 - Q34). Initially, adjusting CBA to be used as a sustainability assessment tool

could make stakeholders throughout the policy process, including politicians, more aware of the sustainability trade-offs that occur when solving a transport problem. However, other methods such as clear sustainability goals, norms, and guidelines might be more effective at achieving sustainability goals in transport. CBA practitioners do not have a large influence on the alternatives considered. Their involvement as well as the use of CBA or other sustainability assessment tools in early Exploratory Study phases can contribute to the prioritization of sustainable alternatives.

One large problem with the presentation of trade-offs in Dutch CBA practice is the presumed autonomous growth of population and mobility in the WLO scenarios. The presumed mobility is expected to cause congestion which for most projects is not in line with policy norms for travel time. This is the reference that the alternatives are compared with. Calculations for travel time benefits and external effects adopt this reference scenario as the baseline. External effects are therefore not considered in comparison to the present situation but relative to a presumed, autonomously developing, future situation. This seems controversial, which shows in the difficulty of explaining it to citizens. To prioritize sustainable practices, it is important to compare the alternatives against the present situation. It might be fruitful to translate the presumed growth of mobility into negative benefits, caused by an increase in congestion and external effects. The alternatives could then alleviate these negative benefits.

Furthermore, assessing all sustainability aspects might not be necessary to prioritize the most sustainable alternatives. Most Dutch CBA experts stress that pilot studies of the relative sizes of the effects are necessary to determine for which impacts specific guidelines for quantitative assessment and valuation should be created. Another factor that limits the prioritization of sustainable alternatives is that it is known that CBA results play a limited role in political decision-making (Annema et al., 2017; Mouter, 2019). Negative CBA results do not form a legal basis for changing or adjusting a project, not in the way that violations of legal limits for air and noise pollution do.

8. Limitations

Some limitations of this study concern the framework for the comparison of the CBA methodology to criteria for sustainability assessment tools. Firstly, the research included a wide variety of sustainability definitions and frameworks but only uses the Three Pillar framework in its ideal framework. More research is necessary to see in what way and to what extent the chosen definition of sustainability influences the usefulness of CBA as a sustainability assessment tool. Secondly, the literature review was focused on gathering concise information and not on providing a comprehensive overview of the field of sustainability science. It did not review all available research on CBA practice in the Netherlands. Instead, the sources diversified across international contexts and included recent additions to the CBA and sustainability debate. Nevertheless, the researcher believes that the literature was gathered in a structured way, and appropriate for the research objective, which did not require a grounded approach.

Other limitations relate to the case study research. The strict selection criteria for CBA cases and the time available limited the number of cases that could be included. As such, these findings might not be as easily transferable to wider CBA practice as presumed. However, the expert survey provided essential validation of the findings. The fact that few CBA projects met the requirements to be included in this study is a result in itself, as CBA practice might not be as straightforward as presumed. The structured CBA practices in this research may be less common, due to the difficult political decision-making that surrounds motorway appraisal projects. Furthermore, only five interviews were conducted to validate the researcher's findings from the documentation analysis. Even though the people in the interviews were highly qualified to discuss

the results, more validation with other interviewees would have solidified the results. With the timeframe of the research in mind, the researcher believes these methods to have been valid for the research purpose.

The case study research was designed to ensure the validity and reliability of the findings. Regarding construct validity, the research extensively reviewed the topic of sustainability assessment in motorway appraisal. The research does not focus on sustainability assessment as a whole, but rather on the specific subsection of the field that is aimed at motorway appraisal. The CBA practices are also measured in the Dutch context, while international literature has been used as the ideal framework. Regarding the external validity of the case study findings, some limitations arise too. Out of all the 40+ projects considered for analysis, only 8 met the strict criteria for this study. That inherently begs the question of whether the cases are typical and not extraordinary within Dutch CBA practice. However, the documentation analysis in combination with the interviews and the ideal framework gives enough credit to the conclusion that the findings can be attributed to wider CBA practice.

The expert survey also has limitations. The number of respondents was limited to 14, out of 30 people that were asked to provide input. In general, surveys of this small scale have downsides. No statistical significance can be derived from this survey design. However, the generalisability of the findings towards wider CBA practice is sufficiently covered with the survey design. Measuring feasibility through the opinions of research subjects is difficult since they might not agree with the premise of the research in the first place. Furthermore, the reasons for (dis)agreement vary greatly, while feasibility simply discusses the practical implications of a proposed change. By asking respondents whether they agree with a specific improvement, and not using the same method to ask them which improvement is feasible, there might be an under-selection of feasible requirements. This leads to more uncertain findings. In general, semi-structured interviews would have been more suitable to validate the findings and identify the feasibility of improvements. This would have led to a deeper understanding of the concepts of the study, for the researcher as well as the respondents. However, time limitations made the researcher choose a structured survey instead, with enough room for respondents to explain their answers.

9. Conclusion

This section contains the conclusions of the study, as well as recommendations for future research and insights related to the scientific fields of Civil Engineering and Public Administration. This research answered the main research question:

To what extent can Cost-Benefit Analysis in ex-ante motorway appraisal projects be used as a sustainability assessment tool?

To answer this research question, several research methodologies were used to identify

a) how CBA is currently used in ex-ante motorway appraisal projects in the Netherlands and,
b) what requirements decision-making tools should meet for them to be used as a sustainability assessment tool,
c) how suitable CBA is as a sustainability assessment tool, in theory, and practice and,
d) how its limitations could be improved with feasible changes

How is CBA used in motorway appraisal projects in the Netherlands?
The findings indicate that CBA is a well-established part of Exploratory Studies in the Netherlands, in which several alternatives to solve a transport highway problem are designed and evaluated using multiple tools. CBA is one of these methods, with a structured approach and clear guidelines, in addition to other tools such as EIA. CBAs are conducted according to the same general CBA framework that is known

internationally. To a certain extent, the CBA practitioners and client have the flexibility to determine which effects are included at what level, following the problem analysis and therefrom derived project goals. In the end, the results of the CBA are presented along with the results of the Exploratory Study and are considered in the final policy decision.

What is the state-of-the-art of Sustainability Assessment, in motorway appraisal projects?
The term sustainability has been well-defined throughout the last decades, through a wide variety of different frameworks and tools. To be able to assess sustainability in motorway appraisal projects, scientific researchers have identified several criteria. By combining two different sets of criteria from Bueno et al. (2015) and Sala et al. (2015), a coherent framework for the suitability of a tool for sustainability assessment could be derived. Sustainability assessment tools in motorway appraisal should:

1) Have boundary conditions to indicate sustainability performance, by clearly adopting limitations for impacts that are deemed unsustainable.
2) Have a full approach towards economic, environmental, and social sustainability impacts. They have to assess the impacts to the fullest extent possible
3) Include strategic sustainability thinking in their analyses, focus on life cycle thinking and use different discount rates for different impacts
4) Show different trade-offs between different types of solutions and indicate uncertainty and risks to the outcomes
5) Account for contextual input and adjust their implementation based on local input and priorities
6) Be transparent about their outcomes and methodology and provide a paper trail for choices made

To what extent can CBA be used as a sustainability assessment tool - in theory?
After comparing these criteria with CBA best practices, it can be concluded that CBA can be used as a sustainability assessment tool, but efforts have to be made to ensure the fulfilment of the six criteria. Sustainability goals and frameworks can be embedded in the boundary orientation of the CBA. The assessment of economic and environmental sustainability is well-established, while most of the impacts related to social sustainability cannot be fully included. However, CBA practice is focused on identifying effects and while these effects might not be monetised, they should be included in the report. A focus on long-term analysis, life cycle thinking, and the use of different discount rates enables the use of CBA as a sustainability assessment tool. If the process surrounding the CBA accounts for contextual input and the results are transparently presented and communicated, CBA fulfils the requirements.

To what extent is CBA used as a sustainability assessment tool - in practice?
The comparison of CBA practices with the ideal framework shows that CBA practice in the Netherlands does not meet the requirements for sustainability assessment tools and can in its current form not be used to prioritize sustainable alternatives. The Dutch CBA practices could be improved on all six criteria for sustainability assessment tools.

The boundary orientation used in Dutch CBA practice is not ambitious regarding the inclusion of sustainability frameworks and limitations. Regarding the full approach, many methods are not sufficient for assessing sustainability impacts, except for methodologies used to assess economic sustainability impacts, such as travel time benefits. While an improvement in the assessment of economic and environmental aspects can be observed in recent projects, the inclusion of social impacts is lacking. Recent cases include limited forms of life cycle assessment for CO2 emissions with rising CO2 prices and assess air and noise pollution in line with best practices. One project included monetised evaluation of cross-ability and landscape degradation. Life cycle thinking is limited to the investment and operation phase, and the cradle and end-of-life phases are often not included. The use of differing discount rates is not consistent throughout the cases. The showing of trade-offs between alternatives could be improved as well, to include

a wide variety of alternatives and to indicate the relative size between project effects and base scenario developments. The CBA practitioners and clients could increase their efforts to be transparent about the results and to account for local input and interests in their analyses.

What are the feasible improvements for CBA as a sustainability assessment tool in the Netherlands? The case study research resulted in 29 concrete improvements. They were evaluated by CBA experts in a survey, to validate the findings and indicate which improvements were feasible. Eleven improvements were marked as feasible, as they are supported by CBA experts and are easy-to-implement.

In general, CBA practitioners must include end-of-life valuations for demolition or expected replacement of new infrastructure and calculate CO2 emissions from cradle to grave. They should estimate safety benefits, noise, and air pollution based on studies for EIA and use a vehicle-kilometre approach for the larger study area. The division of costs and benefits across different stakeholder groups should always be described, as well as a list of local interests that were considered. The client should summarise the CBA findings in the policy documents and include the CBA results in public meetings. CBA practitioners should be present to explain the results. Another feasible improvement for the government and clients is to create a central website for the publication and review of CBA reports, for the CBA community to learn and consistently present the results to the public. Another feasible improvement is for clients and CBA practitioners to take into consideration a wide variety of different alternatives, with the help of a quick-scan CBA in the early phases of the Exploratory Study. Furthermore, Dutch policy analysis organisations and governments should develop a core set of impacts that *at least* have to be considered in motorway appraisal projects, leaving room for adding additional effects.

The other 18 improvements require different levels of additional research from policy analysis organisations and calculation number firms in the Netherlands. This will also determine which improvements would impact the outcomes of the CBA the most. These improvements include the standardization of assessing indirect economic effects and reliability benefits and the estimation of the negative effects of the construction process on residents. Additional research should be conducted to determine practical quantitative estimation and monetisation methods for several environmental and social impacts. These impacts include the effects on culturally significant land, visual landscape degradation and effects on natural areas, recreational or ecological. Current valuation methods are not always applicable and might present an undervaluation of the effect. Moreover, they can be overly resource- and time-consuming to be practically feasible. The social criteria for which additional research is recommended are community disruption and the effects of poor labour conditions in the countries of construction material origin. Furthermore, the guidelines for discount rates should be evaluated from a sustainability perspective and structured tools for Life Cycle Assessment in CBA should be created. Moreover, additional research is necessary for the practical estimation of the external effects of material extraction and production. Regarding contextual input, the added value of including local input in CBAs should be evaluated, especially as a method for deliberation and explanation. For the readability of reports, the positioning of the calculation numbers within the CBA report should be evaluated. Finally, additional research is necessary to determine how CBA practitioners can accurately show the development for all effects caused by the expected autonomous developments. This would indicate the relative impact of the project alternatives and show which problems the project addresses and which could be addressed. Additional research from the calculation number agencies, such as CE Delft is also required, to compare Dutch calculation numbers for external effects to international standards, such as the WHO norms. Dutch calculation numbers take into account effects on comfort and health, but whether the used boundary conditions for when these effects occur differ from international standards is unknown. Calculation number agencies and policy analysis organisations should evaluate whether Dutch calculation numbers for the effects of air and noise pollution could be translated to

QALYs or DALYs and whether there are significant differences between both assessment methods when evaluating the impacts of noise and air pollution.

To what extent can Cost-Benefit Analysis in ex-ante motorway appraisal projects be used as a sustainability assessment tool?

This study has shown that CBA can be used for sustainability assessment if the right practices and methods are put into place. By examining different requirements that exist for tools to be used as a sustainability assessment tool, a thorough and nuanced analysis of CBA theory and practice was made. With the right choices and practices in place, CBA can be used, to a large extent, to provide:

1) a good boundary orientation for sustainability,
2) a full approach towards sustainability impacts,
3) strategic sustainability thinking,
4) the showing of trade-offs,
5) the provision of contextual input,
6) and transparent reporting,

This study has also shown that in practice, CBA needs improvement to be able to be used as a sustainability assessment tool. It has provided suggestions for the improvement of Dutch CBA practices in its role as a sustainability assessment tool in motorway appraisal projects.

Recommendations for future scientific research

This study warrants recommendations for future research into the application of CBA as a sustainability tool. It would be useful to evaluate the meaning of different sustainability definitions and frameworks, since this study largely focused on the Three Pillar Framework for sustainability, despite identifying alternative schools of thought on sustainability. This study was largely focused on the practical Dutch context and more comparative studies into international contexts would shed light on the use of CBA as a sustainability assessment tool.

Insights related to the field of Civil Engineering & Management

The field of Civil Engineering & Management concerns itself with the processes, such as planning, design, maintenance, and construction that surround large civil infrastructure objects, such as roads, railways, bridges, sewage systems, flood protection systems and traffic systems. Sustainability assessment is one of the challenges that this field will have to deal with in the coming decades and lots of research is conducted into making infrastructure and the built environment more sustainable. The challenges the construction industry faces require an integral approach from Civil Engineering to the processes surrounding and the environment their products are built. As such, this study provides insight into how large decision-making processes for motorway infrastructure have a large influence on the sustainability of the outcomes and the ability of engineers to change course at a later phase is limited.

Insights related to the field of Public Administration

The field of Public Administration is focused on the efficient and effective provision of public services and government functioning in line with public values. It studies the interaction between persons, entities, and organisations and how these interactions result in positive or negative outcomes for public service provision. This study gives insight into the use of a technical appraisal tool in a public decision-making process, in which several organisations have their responsibilities and expectations. The framework for sustainability assessment shows that the contextual input and transparency of tools matter just as much as the technical aspects of the assessment. A large portion of the recommendations is focused on improving the transparency and consulting of affected stakeholders in the process.

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11.Appendices

The appendices mentioned in the thesis report are provided in this section. They give detailed insights into the theoretical framework and results.

11.1 Quick Scan for case selection

It contains information on the project name, year of CBA completion, and which firm conducted the CBA. It also shows the problem context of the case, the main alternatives, and the source of this information.

Cases	CBA year	Executor	Problem Description	Main alternatives (different changes)	Source
A20 Nieuwerkerk aan de IJssel-Gouda	2016	RIGO	Bottleneck congestion between nodes Nieuwerkerk and Gouda, limiting factor is aqueduct Gouwe	3 alternatives, widening different sections/closing an on-ramp	RIGO (2019)
N65 Vught-Haaren	2016	RIGO	Liveability impacts of large national roads through villages	4 alternatives, Grade-separated intersections/road/ new untangling routes	RIGO (2016)
A67 Leenderheide - Zaarderheiken	2019	RIGO	Congestion at the node Zaarderheiken near Venlo, widening	3 alternatives, widening different sections/Smart Mobility	RIGO (2019)
A58 Eindhoven Tilburg	2015	Decisio	Congestion on the A58 Eindhoven Tilburg	Widening to 2x3 lanes or 2x2 with ‘rush hour lanes’	Decisio (2015)
A27/A12 Ring Utrecht	2014	Decisio	Congestion on the A27/A12 Ring Utrecht	Prove that the Preferred Decision is profitable, with changing small adjustments	Decisio (2014)
A7/A8 Amsterdam - Hoorn	2019	Decisio	Congestion in the corridor A7/A8 from Amsterdam to Hoorn, with node Zaandam	6 alternatives, ranging from mobility measures to large widening and redesign of node Zaandam	Decisio (2019)
A2 Deil- Vught	2021	Witteveen +Bos	Congestion on the A2	Different new designs of nodes Deil, Waardenburg and Empel	Witteveen+Bos (2021)
N35 Nijverdal Wierden	2014	Arcadis	Congestion and accidents on the N35	Widening to 2x2 lanes with new intersections, two routes	Arcadis (2014)

11.2 Definitions of criteria for sustainability assessment tools

ID	Requirement	Term from literature	Source	Description
1	Boundary Orientation	Boundary-orientation	Sala et al. (2015)	The inclusion of reference values for the assessment to indicate sustainability performance and progress towards sustainability goals or limitations. Levels: (1) No reference, (2) baseline or status quo (3) science- and policy-based thresholds
2	Full approach	Full approach	Bueno et al. (2015)	Analyse the widest range of impacts of a transport project including the so-called three pillars of sustainability — environmental, economic, and social criteria — including equity over generations.
		Comprehensiveness	Sala et al. (2015)	Cover multiple pillars of sustainability
		Integration	Sala et al. (2015)	Estimating sustainability as a whole instead of as a single disciplinary
3	Strategic sustainability thinking	Life cycle approach	Bueno et al. (2015)	Authors widely acknowledge that sustainability assessments should include the whole life cycle of the project and not just one of the stages.
		Strategicness	Sala et al. (2015)	The use of the assessment methodology for strategic use. Levels range from (1) accounting methods, (2) methods that already integrate sustainability principles - e.g. life cycle thinking -and (3) true solution-orientated/change-orientated methods
4	Trade-offs	Rigorous trade-offs[1]	Bueno et al. (2015)	When evaluating the sustainability of transport projects, it is necessary to set the weights of different sustainability criteria to measure better their relative impact
5	Contextual input	Adaptability to the context[1]	Bueno et al. (2015)	In the sustainability arena, there is a need for a more objective way to evaluate projects by considering the sensitivity of the criteria in its geographical and social context.
		Stakeholders' involvement[2]	Sala et al. (2015)	Involvement ranges from mere communication to close interaction in all phases of the assessment
6	Transparency	Transparent approach[1,2]	Sala et al. (2015)	Sustainability appraisal tools and methods should be transparent, rational, and formal instruments to minimize ambiguity — understood as the lack of clarity about the methodological principles — and ensure consistency and accuracy — interpreted as the closeness of measured results to acknowledged accurate results. Values underlying the analysis should be clearly and openly presented

11.3 Overview of sustainability impact definitions

Pillar	Indicator	Definition (adapted from Bueno & Vassallo, 2021)	Differences
Economic	Infrastructure costs (construction/maintenance/operating)	Considers all the investment costs of the project, generally comprising land acquisition, design/legal/administration and construction costs, including maintenance and operating costs	None
	Travel time cost/saving	Represents the cost of time spent travelling. Identifies the project's contribution when reducing congestion	Removed waiting costs, since those are included in the term congestion
	Vehicle operating cost	Permanent costs (e.g. insurance) and operating costs (e.g., fuel consumption and lubricants) derived from operating the vehicle	None
	Accident cost/saving	Covers transport accidents (fatal accidents/injuries/damage-only accidents) that should be assessed according to their severity	None
	Macro-economic impacts	Represents all economic benefits or costs that are not captured directly when evaluating user benefits. Should be incorporated as wider economic impacts	None
Environmental	Energy consumption, resource use and CO_2 emissions	Includes the total energy consumed in the processes of extraction, processing, transportation and fabrication of construction materials and resources. Should also include the most important carbon emissions from the construction-maintenance operation of the road	Split into three different criteria
	Habitat fragmentation and negative effects on species	Considers the overall effect of the project on biodiversity and earth heritage attributes, from the construction stage to the service period. The analysis should include mitigation/compensation/substitution measures, relocation of species, etc.	None
	Air pollution	Covers short-term air quality effects caused by construction/maintenance activities (e.g., dust nuisance). Other air pollutant emissions must be considered during the operation stage (local air pollution/global air pollution)	None
	Noise pollution	Assesses noise associated with the road development, including vehicle noise, frictional noise, and activities derived from road construction and maintenance	None
	Landscape degradation & negative visual impacts	Considers all impacts on aesthetics and landscape resulting from construction activities that adversely affect landforms	None

Social	Community disruption	Covers changes to local interactions caused by a new road. The analysis may include necessary measures to maintain social and economic interactions or an assessment of the impacts on community relations (community split, modifications to travel routes, impacts on tourism, etc.).	This is interpreted as the barrier function of the road and local accessibility
	Impacts on businesses and community services	Evaluates impacts on businesses and community services (e.g., hospitals, churches, schools, parks) when a new road is built, including relocation, loss of clients, etc.	None
	Employment and labour standards	Includes a range of indirect effects such as changes in economic, climate and labour/materials markets due to the construction of new infrastructure. Temporary effects such as job creation should be included in the analysis	This is assumed to be covered under the wider impact effects and labour standards are covered under occupational health
	Distributive effects of the project	Considers significant potential equity impacts, particularly for neighbouring communities and users. The assessment must include how disadvantaged people benefit in terms of time savings, convenience, safety, affordability and health. Connectivity must be specifically considered with a view to transporting disadvantaged people (low-income, disabled, isolated, by gender) and in terms of access to education, employment, and economic opportunities	This is interpreted as the distribution of costs and benefits across different groups of stakeholders.
	Occupational and community health and safety	Covers the effects of work on health, including working conditions and also considers safety and health impacts on the surrounding community	None

11.4 Data sources per case

Case	Data sources
A20 Nieuwerkerk aan de IJssel - Gouda	- RIGO (2019) MIRT Verkenning A20 Nieuwerkerk aan den IJssel – Gouda Maatschappelijke kosten-batenanalyse (MKBA) - Ministerie van Infrastructuur en Waterstaat. (2018). MIRT-Verkenning A20 Nieuwerkerk aan den IJssel - Gouda. Milieueffectrapport Deel 1 - van Ewijk et al. (2015). Rapport Werkgroep Discontovoet 2015. Ministerie van Financiën. - CE Delft (2014). Externe en infrastructuurkosten van verkeer. Een overzicht voor Nederland in 2010 - Ministerie van Infrastructuur en Waterstaat (2019). MIRT Verkenning A20 Nieuwerkerk aan den IJssel - Gouda Participatiedocument - I-1 Interviewngineering firm Exploratory Study from Antea Group 02 -12 -2022) - Interview 2 conductor CBA from RIGO (14 -02 -2023)
N65 Vught - Haaren	- Ministerie van Infrastructuur en Milieu (2016). MIRT Verkenning N65 Vught - Haaren. Maatschappelijke kosten en baten van de onderzochte alternatieven. Ministerie van Infrastructuur en Milieu (2016). Alternatievennota MIRT-Verkenning N65 Vught - Haaren - Ministerie van Infrastructuur en Milieu (2016). Notitie Voorkeursalternatief MIRT-Verkenning N65 Vught - Haaren - Ministerie van Infrastructuur en Milieu (2013).Startbeslissing MIRT Verkenning N65 Vught - Haaren - VughtParticipeert (2017). Waarom is de MKBA N65 niet tijdig aan de gemeenteraad ter beschikking gesteld? - Ministerie van Infrastructuur en Milieu (2016). Samenvatting MIRT-Verkenning N65 Vught - Haaren - I1 Interview engineering firm Exploratory Study from Antea Group 02 -12 -2022) - I2 Interview conductor CBA from RIGO (14 -02 -2023)
A67 Leenderheide - Zaarderheiken	- RIGO (2019). Maatschappelijke kosten-batenanalyse A67 MIRT verkenning A67 Leenderheide - Zaarderheiken - Ministerie van Infrastructuur en Waterstaat. (2019). Milieueffectrapport MIRT-Verkenning A67 Leenderheide - Zaarderheiken - Ministerie van Infrastructuur en Waterstaat. (2019). Structuurvisie (ontwerp) A67 Leenderheide - Zaarderheiken - I1 Interview engineering firm Exploratory Study from Antea Group 02 -12 -2022) - I2 Interview conductor CBA from RIGO (14 -02 -2023))
A58 Eindhoven Tilburg	- Decisio (2015). MIRT Verkenning A58 MKBA Eindhoven - Tilburg MKBA - Ministerie van Infrastructuur en Milieu (2013). Startbeslissing MIRT-verkenning A58 Eindhoven - Tilburg. - I4 Interview conductor CBA from Decisio (14 -03 -2023) - Innova58 (2015). Eindrapportage Uitwerking en Beoordeling Kansrijke Alternatieven - Kennisinstituut voor Mobiliteitsbeleid (2015). Second opinion MKBA A58 Sint Annabosch – Galder en MKBA Tilburg – Eindhoven

A27/A12 Ring Utrecht	- Decisio (2014). MKBA Ring Utrecht - I4 Interview conductor CBA from Decisio (14 -03 -2023) - CPB (2014). Second Opinion MKBA Ring Utrecht - Rijkswaterstaat (2008). Startnotitie Ring Utrecht - Rijkswaterstaat (2014). Voorkeursvariant Ring Utrehct A27/A12
A7/A8 Amsterdam Hoorn	- Decisio (2019). MKBA Corridor Amsterdam – Hoorn. Ministerie van I&W - I4 Interview conductor CBA from Decisio (14 -03 -2023) - Goudappel Coffeing (2018). COmbipakketten MIRT verkenning Amsterdam Hoorn - Minsterie van Infrastructuur en Waterstaat. (2018). Nota van Antwoord - Decisio (2018). Analyse economische concurrentiepositie regio Corridor Amsterdam - Hoorn
A2 Deil Vught	- Witteveen+Bos (2021). MIRT-verkenning A2 Deil - ’s-Hertogenbosch - Vught Maatschappelijke kosten-batenanalyse - I3 Interview conductor CBA from Panteia (13 -03 -2023) - I5 Interview consultant involved in Exploratory Study from Panteia (16-03 -2023) - Witteveen+Bos (2019). MIRT-verkenning A2 Deil - 's-Hertogenbosch – Vught - Witteveen+Bos (2020). MIRT-verkenning A2 Deil-Vught Nota van Antwoord Zienswijzen en advies commissie m.e.r. NRD - definitief 03 - Witteveen+Bos (2021). MIRT-verkenning A2 Deil-‘s Hertogenbosch-Vught Participatieverslag - Witteveen+Bos. (2022). Milieueffectrapport - Hoofdrapport (MER)
N35 Nijverdal Wierden	- Verkenningrapport N35 Nijverdal Wierden

11.5 CBA comparison with ideal framework per case

A20 Nieuwerkerk aan de IJssel-Gouda

ID	Criterion	Score	Explanation
1	Boundary Orientation	Insufficient	There are some legal boundaries for pollutants and noise. There is also a maximum budget. There are project goals, that are solely focused on economic sustainability
2	Full approach		
	Economic	Sufficient	The economic criteria focus on travel time benefits and not wider economic criteria. Investment costs and accident savings could be calculated in more detail
	Environmental	Insufficient	Almost no environmental criteria make it into the CBA and those that do are calculated in comparison to the reference scenario. Included criteria are noise, CO2 and air pollutants.
	Social	Inadequate	Local accessibility is considered accurate, but almost no other social criteria are included in the CBA, even though the EIA does state there are some effects.
3	Strategic sustainability thinking	Insufficient	Effects are calculated for usage, and sometimes construction. The rest of the life cycle is left out. Discount rates do not differ for different times of effects
4	Trade-offs	Sufficient	The different effects are presented in relation to the alternatives. Little variation in sustainability impacts is described though. The results of sensitivity analysis are also shown
5	Contextual input	Insufficient	Even though a participatory process is shown, no mention of it affecting the CBA is made.
6	Transparency	Insufficient	The results can be publicly found and the CBA report is readable and referencing is adequate. However, for due diligence, an interview was necessary. The results were also not presented separately to interested parties.

N65 Vught-Haaren

ID	Criterion	Score	Explanation
1	Boundary Orientation	Sufficient	The problem analysis defined that the project had to improve liveability for the citizens along the road, beyond the legal limits for pollution and noise. The budget was also set.
2	Full approach		
	Economic	Sufficient	Except for wider economic impacts and safety, all economic criteria were taken into account properly
	Environmental	Sufficient	Detailed assessment of noise and visual quality. Other environmental aspects were not taken into account
	Social	Sufficient	Distributive effects of the projects are shown, as well as local accessibility, but other social effects are not included

3	Strategic sustainability thinking	Insufficient	No attention is given to specific discount rates for environmental benefits and costs and life cycle assessment is not included
4	Trade-offs	Insufficient	The alternatives are presented along with the criteria relevant. A little variation in sustainability criteria can be seen
5	Contextual input	Sufficient	The goals of the project were local and priority was given to the monetization of these effects.
6	Transparency	Insufficient	The document was hard to read as agreed to by the second opinion and publication to the public was convoluted

A67 Leenderheide -Zaarderheiken

ID	Criterion	Score	Explanation
1	Boundary Orientation	Sufficient	There are legal boundaries for pollution and noise. There is a maximum budget of 200 mln euros and one no-physical intervention alternative is included
2	Full approach		
	Economic	Sufficient	The economic criteria focus on travel time benefits, and Smart Mobility measures are translated into the traffic model. Wide economic impacts do not apply. Accident savings could be calculated in more detail.
	Environmental	Insufficient	A few environmental criteria make it into the CBA. Calculations based on vehicle kilometres, in comparison to the reference scenario. Included criteria are noise, CO2 and air pollutants.
	Social	Inadequate	Almost no social criteria find their way into this CBA.
3	Strategic sustainability thinking	Insufficient	Effects are calculated for usage, and sometimes construction. Different discount rate for environmental effects is mentioned.
4	Trade-offs	Sufficient	The different effects are presented with the alternatives. Little variation in sustainability impacts is described though. The results of the sensitivity analysis are also shown. Alt 2 was dropped during the CBA.
5	Contextual input	Insufficient	The client is focused on Smart Mobility and consists of different stakeholders. No input was given to stakeholders for the CBA
6	Transparency	Sufficient	The report was not easy to follow for non-experts.

A58 Eindhoven Tilburg

ID	Criterion	Score	Explanation
1	Boundary Orientation	Insufficient	Only two variants were considered and not a wider number of different alternatives. No specific sustainability limitations were adopted. Nitrogen emissions are expected to be compensated. The asphalt used is noise-alleviating, so there is compensation built into the alternatives.
2	Full approach		
	Economic	Sustainable	The CBA report contains information on what is included in the investment costs. Reliability benefits are estimated with a 25 per cent estimate of travel time benefits. Wider economic impacts are expected to be 15 per cent.

	Environmental	Insufficient	Energy consumption, resource use and landscape degradation are not explicitly included. Air pollution and noise pollution are taken into account properly. CO2 price does not rise with the years.
	Social	Insufficient	Mostly taken into account qualitatively, compensation for land acquisition is covered in the investment costs
3	Strategic sustainability thinking	Insufficient	Only one discount rate and only the investment and the operation and usage phases are considered
4	Trade-offs	Insufficient	Only two alternatives are presented with the effects and sensitivity, in relation to the reference scenario. Other alternatives were dropped in the previous phase.
5	Contextual input	Insufficient	Local representation in the involvement of regional governments in the client organisation. There were meetings for powerful stakeholders, citizens could only provide input in information sessions.
6	Transparency	Sufficient	The project website is no longer online, so additional steps were necessary to find the documentation. The CBA was not separately presented. Two pages of the Preferred Decision were spent on the CBA results.

A27/A12 Ring Utrecht

ID	Criterion	Score	Explanation
1	Boundary Orientation	Insufficient	Only one alternative with two small variations was analysed because the need for CBA was a political assignment. Noise pollution will be alleviated in a separate project. The budget was allocated for the above-law compensation for nature loss.
2	Full approach		
	Economic	Sustainable	The first time a pilot study with VoR and statistical variation was taken, a 25 per cent standard is included. Complete replacement is included after 100 years.
	Environmental	Insufficient	Compensation for Amelisweerd and part of the EHS natural areas, but no estimate of the recreational value. Air and noise pollution is negated through reference scenario compensation.
	Social	Insufficient	No mention of most of the social criteria. Cultural heritage is estimated qualitatively.
3	Strategic sustainability thinking	Insufficient	One discount rate and focus on the investment and usage phase, although replacement after 100 years is also included.
4	Trade-offs	Inadequate	Only two variants are presented about the reference scenario, except for the effects on maintenance and congestion.
5	Contextual input	Insufficient	No information could be found on this. Interviewee 4 indicated that efforts to address local concerns were made, and the local concerns were known so the participatory process was toned down.
6	Transparency	Sufficient	The documentation is found on the project website and the documentation is accurately presented. The CBA methodology is explained, but no separate presentation of the CBA was part of the project.

A7/A8 Amsterdam – Hoorn

ID	Criterion	Score	Explanation
1	Boundary Orientation	Insufficient	Multiple project goals besides congestion. There is also a focus on the economic position of the region and acceptable negative consequences to the liveability of the region but without serious practical issues. Wide variety of alternatives, with mobility management and public transport package.
2	Full approach		
	Economic	Sufficient	Most criteria are included to the best of Dutch CBA practice, but not according to the ideal framework. This concerns reliability and wider economic benefits. Lacking safety benefits calculations.
	Environmental	Sufficient	There is an increasing CO2 per tonne price, and noise pollution is estimated according to the ideal framework. These scores contribute to a sufficient score for environmental sustainability
	Social	Inadequate	Almost no social criteria are included in the CBA, and if they are included that the discussion is qualitative. This is mostly because the CBA report does not mention them.
3	Strategic sustainability thinking	Insufficient	One discount rate and only two life cycle phases are included.
4	Trade-offs	Sufficient	A wide variety of alternatives is presented with sensitivity analyses, but only in relation to the reference scenario.
5	Contextual input	Insufficient	Local representation and presentation were provided for the executives of the involved and affected municipalities but for the public
6	Transparency	Insufficient	Results are findable and the report is well-written. There was no public presentation of the results and in the Preferred Decision, not much text is spent on the CBA results.

A2 Deil- Vught

ID	Criterion	Score	Explanation
1	Boundary Orientation	Insufficient	The goal was to improve congestion on the A2. After 2040 mobility is stable. Another boundary condition is that local mobility could not worsen. Legal limits for pollution apply.
2	Full approach		
	Economic	Sustainable	The only non-ideal framework criteria are vehicle costs and wider economic impacts. The average comes out to a score of 4, sustainable.
	Environmental	Insufficient	Except for CO2 emissions, which are estimated according to the ideal framework, all other environmental criteria are only taken into account qualitatively.
	Social	Insufficient	Most of the EIA assessment is transferred to the CBA report which makes that most criteria are assessed qualitatively.
3	Strategic sustainability thinking	Sustainable	Discount rates are different for external effects and in line with the ideal framework. More life cycle impacts are taken into account, with an LCA for CO2 emissions.

4	Trade-offs	Sufficient	4 alternatives were presented in relation to the reference scenario, with sensitivity analysis
5	Contextual input	Sufficient	Attention was paid to local problems and with local input, but not specifically to the CBA
6	Transparency	Sufficient	The report was transparent, and the results were presented to the public, though not in a separate meeting. The CBA was presented to the client and local governments. The results are included in the structure vision. Calculation numbers are provided where they are used.

N35 Nijverdal Wierden

ID	Criterion	Score	Explanation
1	Boundary Orientation	Insufficient	Only improve congestion and safety, with a maximum budget and legal limitations, no more ambition.
2	Full approach		
	Economic	Sufficient	On the lower side of sufficient, the infrastructure costs and vehicle costs are calculated. Accident saving is monetised well, but wider economic impacts are not mentioned.
	Environmental	Inadequate	Only noise pollution is mentioned, and the effect is deemed positive in relation to the reference scenario.
	Social	Inadequate	No social effects are mentioned in the CBA report.
3	Strategic sustainability thinking	Insufficient	The discount rate is not mentioned, and the CBA is focused on investment and usage.
4	Trade-offs	Insufficient	For the effects, calculated the differences between the variants are presented in relation to the reference scenario.
5	Contextual input	Insufficient	Since safety was a local project goal it is well included. A large participatory process was held, but not reflected in the CBA
6	Transparency	Insufficient	A basic explanation of the CBA methodology is included, but almost no calculation numbers are given. Methodologies for effect assessment are not explained. The CBA ratios are shown as a part of the EIA.

11.6 Interview and document analysis results per case

Case 1: A20 Nieuwerkerk aan de IJssel - Gouda

Indicator	Comparison to ideal framework	Score	Resulting Question
Boundary orientation	No specific policy values are set other than legal limitations for noise pollution and certain legal limits for NO2 and PM10. The limits are difficult to determine from the CBA study. The budget is a boundary orientation (173 mln for maximum widening if necessary) as well as existing infrastructure (aqueduct Gouwe). The reference scenario contains the other boundary conditions, with projects in the area that are expected to happen and autonomous growth of mobility.	2	Interview 1 - Q1, Q2, Q6, Q7, Q9 Interview 2 - Q1, Q5, Q6
Travel time benefits and reliability benefits	This is calculated based on the NRM 2017 model, compared to the reference situation. The value of time is used to monetise. Reliability and effects on local roads are considered as well. The benefits are split out per vehicle group, with their calculation numbers. Reliability benefits are estimated using the model as well, with the Value of Reliability	4	Interview 1 - Q17 Interview 2 - Q2, Q3, Q4, Q9
Infrastructure costs	Calculated by Rijkswaterstaat for construction and maintenance. It is unclear whether RV-value is included and what the level of detail in the calculations is. Complete replacement after 100 years is likely included.	3	Interview 1 - Q14 Interview 2 - Q10
Accident/safety cost saving	Based on the number of average costing accidents per kilometre driven. The document mentions the probability of an accident could be calculated, but that it was not available. Price per kilometre = -.07-0.11 cent. Rijkwaterstaat provides numbers for the value of human life (6.5 mln euros, but this is not used).	3	Interview 2 - Q13
Vehicle costs	Vehicle costs are mentioned in the document, but no differences in distance travelled occur	3	-
Wider economic impacts	According to the CBA report, the wider economic effects do not apply to the case. The executor indicated in interview 2 that they agreed to not include wider economic impacts in the 1990s, and that is what the company has done since.	1	Interview 2 - Q15
Energy consumption	Is not mentioned in the CBA. It is qualitatively assessed in the EIA. Alt 3 is mentioned as being '2.5 - 1.5' times more energy-consuming, but the numbers are vague. Numbers for energy consumption during usage (cars/vehicle kilometres) are also included but not used in the CBA. According to interview 2, energy consumption is included in the investment costs, but not for the entire life cycle and not explicitly for sustainability.	2	Interview 2 - Q16
Resource use (Abiotic depletion)	Not mentioned in the CBA, mentioned in the EIA, but assumed is that energy consumption covers this indicator. There are no details regarding different material choices. According to interview 2, resource use is included with market prices in the investment costs, without specifically focusing on sustainability and abiotic depletion.	2	Interview 2 - Q17
CO_2 emissions (Global Warming Potential)	Based on the number of vehicle kilometres, but since that does not change relative to the reference scenario. There is zero effect, despite more traffic than in the current situation. The numbers are not split over different modalities.	3	Interview 1 - Q13 Q14, Q15 Interview 2 - Q11

Habitat fragmentation and negative effects on species	EIA foresees the loss of habitat, but it is not mentioned in the CBA. No costs for mitigating measures are included. Interviewee 2 mentioned that methods for calculations existed at the time, but the effects were too small to include them. If land needs to be acquired, the costs will be in the investment costs.	2	Interview 1 - Q12 Interview 2 - Q19
Air pollution (acidification & health)	This is calculated based on vehicle kilometres, multiplied by a calculation number. Since the number of kilometres does not change relative to the reference scenario, the final number is near 0.	3	Interview 1 - Q13 Interview 2 - Q20
Noise pollution	This is calculated based on vehicle kilometres, multiplied by a calculation number. Since the number of kilometres does not change relative to the reference scenario, the final number is near 0.	3	Interview 1 - Q13
Landscape degradation	Not mentioned in the CBA. In the EIA, poplar trees being removed are mentioned, but this effect is not quantified.	1	-
Community disruption (accessibility)	Not mentioned in CBA. From the EIA, it can be found no barrier or accessibility effects are expected.	1	-
Impacts on businesses and community services	Not mentioned in the CBA, from the EIA, the effect of Alt 3. is expected to be larger, but no quantification.	1	-
Distributive effects	Not mentioned in CBA. From the EIA, it can be found no skewed distributive effects are expected	1	Interview 2 - Q26, Q27
Occupational and community health safety	The effects on community health and labour conditions in other countries are not mentioned in CBA or EIA.	1	Interview 2 - Q24 Interview 2 - Q25
Cultural heritage	Not mentioned in CBA. EIA foresees archaeological finds, but no quantification or inclusion of archaeological costs. According to interview 2, this should be in included in the investment costs.	2	Interview 2 - Q28
Cradle-to-cradle life cycle thinking for all project materials	In this CBA, most indicators focus either on the use phase or investment phase, but only for easily quantifiable things. No regard is given to the end-of-life phase or supply chain external effects.	2	Interview 1 - Q14, Q15 Interview 2 - Q11, Q17
Lower/different discount rates	The discount rate was 4.5 per cent for the infrastructure project. It is unclear whether other discount rates were used.	2	Interview 1 - Q10, Q11 Interview 2 - Q29
Rigorous trade-offs	Relative weights of benefits and costs are included. The three alternatives are shown in relation to the reference scenario. The reference scenario impact is not presented.	3	Interview 2 - Q7 Interview 2 - Q30
Stakeholder Involvement	A participatory process and document on the output of suggestions are included in the Exploratory Study files. The CBA is not mentioned in this document. A wide variety of stakeholders, powerful and local, were included in the Exploratory Study, but not specifically for the CBA.	3	Interview 1 - Q5, Q16, Q19 Interview 2 - Q31
Local variation of weights and priorities	The CBA report does not contain anything on this and was made using national guidelines. The problem analysis provides some local problems. Local input was used, but not for the CBA report.	1	Interview 1 - Q8, Q2 , Q27
Presentation of results to the public	Exploratory Study reports were easy to find. The website is still online and documentation is clearly ordered. The CBA was not mentioned in the information meeting for interested people. In the final document on the Preferred Decision, only the ratios are mentioned.	2	Interview 1 - Q18, Q19 Interview 2 - Q35, Q36
Explanation of methodology, uncertainty, choices	On the surface, a high amount of information was present in the document and referencing was accurate, directly where it was relevant. The explanation of the CBA methodology is limited.	2	Interview 2 - Q33 Interview 2 - Q34

Case 2: N65 Vught - Haaren

Indicator	Comparison to ideal framework	Score	Resulting Question
Boundary orientation	The problem analysis states there are problems with pollution, environmental quality and noise. The only legal limit that is being violated is the noise, but improving the barrier function of the road is seen as a base requirement. Safety is also an important project goal.	3	Interview 1 - Q1, Q3, Q4, Q6, Q7 Interview 2 - Q1, Q5, Q6, Q22
Travel time benefits and reliability benefits	Travel time benefits are calculated using a combination of a regional traffic model and a national model. Reliability is estimated as 25 per cent of the travel time benefits and not calculated by multiplying the Value of Reliability calculation numbers with variability in trip time.	3	Interview 1 - Q17 Interview 2 - Q2, Q3, Q4, Q9
Infrastructure costs	Calculated by Rijkswaterstaat, based on infrastructure measures, cycling infrastructure, and noise barriers. It is unclear whether the residual value is included.	3	Interview 1 - Q14 Interview 2 - Q10
Accident/safety cost saving	More accidents because of more (local) road traffic, monetised using costs per kilometre, multiplied with road and vehicle type. Cycling safety improvements are not monetised, since no accidents with cyclists have occurred. The effect is qualitatively marked with a plus.	3	Interview 2 - Q12 Interview 2 - Q13
Vehicle costs	The extra travel distance was considered in the distance and associated fuel consumption, quantified and monetised.	3	-
Wider economic impacts	Not mentioned in CBA and/or Exploratory Study. Interviewee 2 said their firm does not include these anymore.	1	Interview 2 - Q15
Energy consumption	Not mentioned in the CBA/or Exploratory Study. Interviewee 2 said these should be present in the investment costs, but this is not verifiable. Given that this was not yet part of the EIA at the time, this factor is marked with a 2	2	Interview 2 - Q16
Resource use (Abiotic depletion)	Not mentioned in the CBA/or Exploratory Study. Interviewee 2 said these should be present in the investment costs, but this is not verifiable. Given that this was not yet part of the EIA at the time, this factor is marked with a 2	2	Interview 2 - Q17
CO_2 emissions (Global Warming Potential)	The CO2 emissions were covered in a general air pollution calculation number, multiplied by changes in vehicle emissions.	3	Interview 1 - Q13, Q14 Interview 2 - Q11, Q18
Habitat fragmentation and negative effects on species	Not mentioned in the CBA. It is estimated quantitatively in the Exploratory Study. Nitrogen emissions for Natura2000 areas are calculated but the effects are not monetised	1	Interview 1 - Q12 Interview 2 - Q19
Air pollution (acidification & health)	A general calculation number for pollution is multiplied by the increase in vehicle kilometres.	3	Interview 1 - Q13 Interview 2 - Q20
Noise pollution	The effects of the project are different for different households. Some houses experience more nuisance, while others have less. It is monetised with the monetary value of each nuisance class. The net effect is slightly better than the reference scenario	4	Interview 1 - Q13
Landscape degradation has negative impacts (visually)	The degradation is caused by noise pollution barriers. The effects are estimated for road users (cars and cyclists), citizens, intrinsic value and potential repairs. Potential repairs and intrinsic value do not play a role. The effects on cars and cyclists are noted but not quantified. The effect for citizens is calculated with the residential value of their houses.	3	Interview 1 - Q22 Interview 1 - Q23 Interview 2 - Q23

Community disruption (accessibility)	The barrier criterion is addressed using travel time benefits for cross-ability. This includes an analysis of cyclists and the Value of Time for redesigning intersections for cyclists.	4	Interview 1 - Q20 Interview 1 - Q21
Impacts on Businesses and community services	This is not mentioned in the CBA. Interviewee 2 indicated accessibility of local businesses is taken into account in the travel time benefits. Nuisance during realisation is not included.	2	Interview 1 - Q13 Interview 2 - Q37
Distributive effects of the project	The costs and benefits per involved town are provided. A distribution over different stakeholders: citizens, road users and the government are also included.	4	Interview 2 - Q26 Interview 2 - Q27
Occupational and community health and safety	This was not mentioned in the CBA or the EIA, it does not play a role in Dutch CBA	1	Interview 2 - Q24 Interview 2 - Q25
Cultural heritage	This is not mentioned in CBA. The Exploratory Study report expects little furth archaeological research is necessary based on previous projects.	2	Interview 2 - Q28
Cradle-to-cradle life cycle thinking for all project materials	Everything in the CBA is focused on the year 2030-2120. The CBA and Exploratory Study don't mention additional life cycle effects. They focus on the usage and investment phase.	2	Interview 1 - Q14, Q15 Interview 2 - Q11, Q17
Lower/different discount rates for environmental effects	The discount rate is 5.5 per cent. During the study, the recommended rate changed to 4.5 per cent, which was included in the sensitivity analysis. There is no mention of different discount rates for environmental effects	2	Interview 1 - Q10 Interview 1 - Q11 Interview 2 - Q29
Rigorous trade-offs: present relative weights of costs and benefits	The alternatives are a comparison of different construction blocks and effects on all relevant criteria are shown, in relation to the reference scenario. The sensitivity analysis is clear. Results are represented in tables.	2	Interview 2 - Q7 Interview 2 - Q30
Stakeholder Involvement	This is not mentioned in the CBA and not the Exploratory Study report either. In the Decision to Start, a list of stakeholders and intentions for participation is created. The municipalities of Vught and Haaren were involved closely. From Interviews 1 and 2, it can be concluded that there was a lot of powerful stakeholder involvement.	3	Interview 1 - Q8, Q5 Interview 2 - Q7, Q31
Local variation of weights and priorities	Local liveability effects are of high priority. More attention was paid to estimating effects and monetising them.	3	Interview 1 - Q1, Q2, Q8, Q24, Q27 Interview 2 - Q7, Q32
Presentation of results to the public	The results were all put together online in June 2016 by the Ministry, even though the first CBA was already concluded. It is unclear whether the CBA was presented with other documents to the public. The rest of the N65 documentation is difficult to find, as the project has been continued by the Province of Brabant and the project website was taken offline. In the available documentation on the Preferred Decision, the CBA results are not mentioned.	2	Interview 1 - Q18 Interview 1 - Q19 Interview 2 - Q35 Interview 2 - Q36
Explanation of methodology, uncertainty and choices	The CBA is relatively hard to read, as agreed on by the second opinion of the KiM. A one-page general explanation is given for the CBA methodology.	2	Interview 1 - Q19 Interview 2 - Q33, Q34

Case 3: A67 Leenderheide - Zaarderheiken

Indicator	Comparison to ideal framework	Score	Resulting Question
Boundary orientation	Alternative 1 is a non-infrastructure alternative, a boundary setting to take into account. Legal limitations for pollution and noise apply. The maximum budget is about 200 mln. These boundary conditions form a part of sustainability but cannot be seen as a sustainability form itself. Main focus on smart infrastructure measures, given that its part of the Smart Mobility measures project	3	Interview 1 - Q1, Q3, Q4, Q6, Q7, Q25 Q26 Interview 2 - Q2, Q5, Q6
Travel time benefits and reliability benefits	The Smart Mobility measures were translated into effects for the intensity or capacity of links in the traffic models. In the end, it results in a capacity increase of 5 -7 per cent and demand control of 10-20 per cent in rush hour. The practitioners of the CBA consulted with (client) stakeholders on the implementation, although the report is not transparent on this process	3	Interview 1 - Q17, Q30, Q31, Q32 Interview 2 - Q3, Q4,Q8,Q9
Infrastructure costs	These costs are based on calculations for investment costs and maintenance.	3	Interview 2 - Q10
Accident/safety cost saving	This value is based on vehicle kilometres multiplied by the probability of accidents per road type and vehicle. A specific accident study was carried out but only had qualitative results. An increase in safety is expected in Alt 1 and 2 since the road design changes, this is not quantitatively assessed	3	Interview 1 - Q28, Q29 Interview 2 - Q12, Q13,Q14
Vehicle costs	The alternatives reduce the travel distance, which leads to lower fuel costs	4	-
Wider economic impacts	This is mentioned in the CBA, because freight transport is a major part of the project, but not assessed qualitatively. This resulted in a score of 1.	1	Interview 2 - Q15
Energy consumption	According to Interviewee 2, this should be in the investment costs, but this is not verifiable and not based on a sustainability impact calculation. The effect is fundamentally underestimated in the current methodology. That is why a score of 2 is awarded.	2	Interview 2 - Q16
Resource use (Abiotic depletion)	According to Interviewee 2, this should be in the investment costs, but this is not verifiable and not based on a sustainability impact calculation. The effect is fundamentally underestimated in the current methodology. That is why a score of 2 is awarded.	2	Interview 2 - Q17
CO_2 emissions (Global Warming Potential)	This is based on vehicle kilometres multiplied with calculation numbers for pollution of each fuel type	3	Interview 1 - Q13, Q14 Interview 2 - Q11
Habitat fragmentation and negative effects on species	This is not mentioned in the CBA, although it is mentioned in Exploratory Study. The effects are not large, but there are effects.	1	Interview 1 - Q12 Interview 2 - Q19
Air pollution (acidification & health)	This is based on vehicle kilometres multiplied with calculation numbers for pollution of each fuel type	3	Interview 1 - Q13 Interview 2 - Q20
Noise pollution	This is based on vehicle kilometres multiplied with calculation numbers for pollution of each fuel type	3	Interview 1 - Q13 Interview 2 - Q14
Landscape degradation has negative impacts (visually)	This is mentioned in the CBA report. It does not apply to this project. Further explanation is not given.	2	
Community disruption (accessibility)	This is not mentioned in the CBA report.	1	

Impacts on Businesses & community services	This is not mentioned in the CBA report.	1	
Distributive effects of the project	This is not mentioned in the CBA report.	1	Interview 2 - Q26
Occupational & community health and safety	This is not mentioned in the CBA report.	1	Interview 2 - Q24 Interview 2 - Q25
Cultural heritage	This is not mentioned in the CBA report.	1	Interview 2 - Q28
Cradle-to-cradle life cycle thinking for all project materials	All focused on the usage phase, except for infrastructure costs, since those are calculated over construction	2	Interview 1 - Q14 Interview 2 - Q17
Lower/different discount rates for environmental effects	The same discount rate of 4.5 per cent as for other projects. Specifically mentioned that the discount rate for environmental external effects is 3 per cent.	2	Interview 1 - Q10, Q11 Interview 2 - Q29
Rigorous trade-offs: present relative weights of costs and benefits	Three different alternatives are evaluated in the CBA report. They cover measures that focus on mobility demand and capacity management and increasingly include bigger adjustments to physical infrastructure. The effects are presented in relation to the reference scenario.	3	Interview 2 - Q7 Interview 2 - Q30
Stakeholder Involvement	The level of stakeholder involvement is not mentioned in the CBA report. However, from Interviews 1 and 2 it follows that Smartwayz, the client was highly involved in the formulation of the CBA. This is a regional collaboration that focuses on the inclusion of Smart Mobility measures in infrastructure projects. In the participatory process report, it can be seen that substantial efforts were taken to inform and consult (local) stakeholders. The focus was on identifying problems and finding solutions and potential combinations with other projects and policies. In the final documentation, little additional addressing of these problems can be found	2	Interview 2 - Q31
Local variation of weights and priorities	The focus was on implementing Smart Mobility measures in the project. Further represented local priorities are not known, since they are not mentioned in the CBA report. From the interviews only general statements were made, which focus on regarding analyses	2	Interview 1 - Q2 Interview 1 - Q27
Presentation of results to the public	The CBA report is easy to find online, and the other documents from the Exploratory Study are difficult to find. The documentation for the Exploratory Study has been taken offline since the Plan Detailing Phase started. On the website Platform Participatie, the documentation is still traceable. In the EIA, only the scores of the CBA are given in one small paragraph. The studies were presented in an information evening, but not specifically focused on the CBA.	3	Interview 1 - Q18,Q19,Q33 Interview 2 - Q35, Q36
Explanation of methodology, uncertainty and choices	There is no general explanation of the CBA and what it does. Overall, the document is well-referenced.	2	Interview 2 - Q33 Interview 2 - Q34

Case 4: A58 Eindhoven - Tilburg

Indicator	Comparison to ideal framework	Score	Resulting Question
Boundary orientation	There are the same legal limits for noise and air pollution, as in other projects. Other project goals are the improvement of accessibility and fit in the budget of 317 mln euros. Potential nitrogen effects are considered, but those are understood to be compensated. Another boundary condition was that the alternatives should fit the shortened MIRT procedure, and therefore only two alternatives with the same route are considered.	2	Interview 4 - Q15 Interview 4 - Q21 Interview 4 - Q31
Travel time benefits and reliability benefits	The travel time benefits are calculated with national traffic models. The reliability benefits. Reliability benefits are 25 per cent. Interview 4 follows that this was a well-established estimation, even though a Value of Reliability calculation is more suitable. The traffic models at the time were not capable of generating this output.	3	Interview 4 - Q1 Interview 4 - Q2 Interview 4 - Q24
Infrastructure costs	The report mentions what is covered in the investment costs. It covers construction costs, real estate, engineering costs, permits, insurance, archaeological research and mitigating measures. Costs for maintenance are also included. Residual value and costs for replacement are not mentioned. Avoided maintenance costs from the reference scenario are calculated.	4	Interview 4 - Q24
Accident/safety cost saving	This is estimated for both probabilities of accidents in the study area for which a traffic accident study was made. Outside of this study area, a general vehicle kilometres multiplication with calculation numbers is given.	3	
Vehicle costs	Calculated using fuel costs per kilometre, through changing travel distance	4	
Wider economic impacts	The wider economic impacts are expected to be 15 per cent of the travel time benefits. This number falls in the middle of the well-accepted bandwidth 0 and 30 per cent. The economic situation in the region was studied and through expert judgement, this number was chosen.	3	Interview 4 - Q3
Energy consumption	According to Interviewee 4, this should be in the investment costs, but this is not verifiable and not based on a sustainability impact calculation. The effect is fundamentally underestimated in the current methodology. That is why a score of 2 is awarded.	2	Interview 4 - Q38
Resource use (Abiotic depletion)	According to Interviewee 4, this should be in the investment costs, but this is not verifiable and not based on a sustainability impact calculation. The effect is fundamentally underestimated in the current methodology. That is why a score of 2 is awarded.	2	Interview 4 - Q38
CO_2 emissions (Global Warming Potential)	This is calculated by multiplying the emissions per vehicle kilometre of cars and trucks with the CO2 price per ton, which is 86.59 euros.	3	
Habitat fragmentation and negative effects on species	The effects on species and ecosystems are only qualitatively assessed in the CBA report.	2	Interview 4 - Q22 Interview 4 - Q23
Air pollution (acidification & health)	This is calculated by multiplying the increase of vehicle kilometres with calculation numbers for the damage by air pollution in urban and rural areas. They are valued against the legal limits for air pollution. The Netherlands Commission for Environmental Assessment advised making use of DALYs. The CBA practitioners do not support this, since it is not standardized in the CBA methodology	3	Interview 4 - Q8
Noise pollution	In the study area of the EIA, noise pollution was determined per household. Outside of the study area, the effects were calculated with a multiplication of vehicle kilometres with a	3	

	calculation number. The alternatives already include mitigating measures in the investment costs, the noise pollution decreases relative to the reference scenario. Note: The WHO recommends using 45 dB for daytime and 40 dB for night-time, instead of 50 dB in this study.		
Landscape degradation	This is not mentioned in the CBA report.	1	
Community disruption (accessibility)	The measures to alleviate nuisance for road users during realisation are included in the investment costs, according to Interview 4. This is not estimated using travel time effects. The cross-ability of the road is not included.	2	Interview 4 - Q10 Interview 4 - Q24
Impacts on Businesses and community services	The compensation for land acquisition is covered in the investment costs. In land acquisition, the economic potential of the land function is compensated. This covers the damage that is done to businesses. Nuisance during realisation is not included.	3	Interview 4 - Q11 Interview 4 - Q24
Distributive effects of the project	Even though the introduction mentions the CBA can give insights into the division of costs and benefits, no additional information is given. According to Interview 4, this did not play a role in the project and therefore the division was not made, even though it is common.	1	Interview 4 - Q9
Occupational and community health and safety	This is not mentioned in the CBA report and according to Interview 4, this is not taken into account.	1	Interview 4 - Q12
Cultural heritage	This is mentioned but only qualitatively, costs for delay or archeologic research are not included.	2	
Cradle-to-cradle life cycle thinking for all project materials	The only phases that are considered are the investment and use phases.	2	Interview 4 - Q16
Lower/different discount rates for environmental effects	The discount rate for the entire project is 5.5 per cent. There is no mention of using different discount rates.	2	Interview 4 - Q17 Interview 4 - Q27
Rigorous trade-offs: present relative weights of costs and benefits	All effects of the alternatives are presented, including sensitivity analyses. Other alternatives were dropped in the first phase of the Exploratory Study. As such only two variants are included in the final CBA report, which does not cover the wide variety of possible solutions. Interviewee 4 agrees the CBA should be involved sooner.	2	Interview 4 - Q15 Interview 4 - Q31
Stakeholder Involvement	The CBA report does not mention this. According to Interview 4, local representation was present in the client organisation Innova58. In the Preferred Decision document, it can be seen that several powerful stakeholders, such as municipalities and organisations were included in special sessions, while citizens could make suggestions in an information session.	2	Interview 4 - Q18 Interview 4 - Q29
Local variation of weights and priorities	Local projects are included in the sensitivity analysis, but the goals are national. Interview 4 indicated that no specific local priorities were included.	1	Interview 4 - Q18 Interview 4 - Q28
Presentation of results to the public	The documentation of the project was difficult to find, in part because the project has been paused and another track was added throughout the Exploratory Study. After contact with the project organisation, the documentation could be located. Two pages in the Preferred Decision document are spent on the CBA results.	3	Interview 4 - Q30
Explanation of methodology, uncertainty and choices	Documentation and referencing are appropriate. The second opinion by the KiM states the process was followed correctly. The document is well-referenced, even though the calculation numbers are all given in the appendix. It has an explanation of the CBA.	3	Interview 4 - Q19

Case 5: A27/A12 Ring Utrecht

Indicator	Comparison to ideal framework	Score	Resulting Question
Boundary orientation	Reference scenarios are based on regular maintenance and therefore the alternatives have avoided investment costs. Nature removal (EHS) will be lawfully compensated. There is no Decision to Start, so it is difficult to determine the boundary conditions of the problem analysis. Goals are to safely solve the congestion, which means widening a section of road next to a nature area is necessary. The CBA is made to determine whether the investment is worth it. Only two variants were considered.	2	Interview 4 - Q6 Interview 4 - Q7 Interview 4 - Q14 Interview 4 - Q15
Travel time benefits and reliability benefits	These are calculated over four different trip categories. Nuisance during construction is not included in the calculation but is only assessed qualitatively. Reliability savings are estimated at 25 per cent of the travel time benefits, with a pilot study for the value of reliability using statistics.	4	Interview 4 - Q1 Interview 4 - Q2
Infrastructure costs	These include mitigation of congestion during construction. Specific risk posts are included, with a value of 50 mln euros. The costs also include complete replacement after 100 years. The alternatives also include avoided costs for large maintenance.	4	Interview 4 - Q1
Accident/safety cost saving	These savings are calculated for the probability of accidents in the study area. In the larger network, safety costs are estimated through the multiplication of vehicle kilometres with a calculation number.	4	
Vehicle costs	Calculated with the costs per vehicle kilometre, based on fuel costs.	3	
Wider economic impacts	These are estimated to be 15 per cent, on a bandwidth of 0-30 per cent. There is a sensitivity analysis for the bandwidth effects, but an analysis for choosing 15 per cent is lacking.	3	Interview 4 - Q3
Energy consumption	According to Interviewee 4, this should be in the investment costs, but this is not verifiable and not based on a sustainability impact calculation. The effect is fundamentally underestimated in the current methodology. That is why a score of 2 is awarded.	2	Interview 4 - Q38
Resource use (Abiotic depletion)	According to Interviewee 4, this should be in the investment costs, but this is not verifiable and not based on a sustainability impact calculation. The effect is fundamentally underestimated in the current methodology. That is why a score of 2 is awarded.	2	Interview 4 - Q38
CO_2 emissions (Global Warming Potential)	The CO2 emissions are calculated based on the multiplication of vehicle kilometres with a CO2 price per tonne, which is 27 euros, which is quite low.	3	
Habitat fragmentation and negative effects on species	Some parts of the national ecological green structure are being influenced and compensation is necessary, 5 hectares for every hectare lost needs to be compensated. The ecological value of the land is restored with this. The costs for this are accounted for at a discounted.	3	Interview 4 - Q4 Interview 4 - Q5 Interview 4 - Q22
Air pollution (acidification & health)	Since there is a National Alleviation programme for air pollution, in the reference scenario, no effects are estimated. It is assumed that those investments are not part of the project.	2	Interview 4 - Q8
Noise pollution	The reference scenario already contains measures to alleviate noise pollution. As such, the assumption is made these measures will alleviate all effects of the alternatives in the direct study area as well. Here a base value of 40 dB is used. For the network effects in the larger area, a multiplication of vehicle kilometres and calculation number is used.	3	

Landscape degradation has negative impacts (visually)	An extra 60 mln euros has been reserved in the investment costs to compensate for the lost quality. This will be used to build a green connection to the nature area of Amelisweerd. There is no mention of an assessment of visual quality though.	2	
Community disruption (accessibility)	This is not mentioned in the CBA report. According to Interview 4, the cross-ability of the road is not affected by the new entrance to the nature area, since the area is already included.	2	Interview 4 - Q10
Impacts on Businesses and community services	This is not mentioned in the CBA report. According to Interview 4, the costs of land acquisition are in the investment costs, but few businesses would be affected.	2	Interview 4 - Q11
Distributive effects of the project	This is not mentioned in the CBA report. From Interview 4 it can be determined that 80 per cent of the benefits do not go to the city and residents of Utrecht.	1	Interview 4 - Q9
Occupational and community health and safety	This is not mentioned in the CBA report.	1	Interview 4 - Q12
Cultural heritage	In the CBA report the cultural/recreational value of Amelisweerd is assessed but only qualitatively. This is transparently done. However, there were methodologies to assess the economic value of nature in a specific location. Interviewee 4 does not agree. Those methods did not apply to this area.	2	Interview 4 - Q5
Cradle-to-cradle life cycle thinking for all project materials	Only the investment and usage phases are included, including full replacement after 100 years. The residual value, construction and supply chain of construction materials are not included.	2	Interview 4 - Q16
Lower/different discount rates	The entire project has the same discount rate of 5.5 per cent, with reference	2	Interview 4 - Q17
Rigorous trade-offs: present relative weights of costs and benefits	The effects are summarised with sensitivity analyses for important factors. However, the effects are only presented in relation to the reference scenario. The only effects that are presented for the reference scenario are the increased congestion and maintenance costs. Only two variants are evaluated, not a wide variety of alternatives. Interviewee 4 indicated that this was a political CBA, not from the Exploratory Study and thus only one alternative was researched.	1	Interview 4 - Q14
Stakeholder Involvement	The CBA report does not contain any information on this. Since the Exploratory Study on this case spans many years of complex research, no direct information on the involvement of stakeholders in the CBA could be found. According to Interviewee 4, the involvement was kept to a minimum since the case was politically charged and the stakeholder interests were already known. They chose to incorporate local interests in the CBA.	1	Interview 4 - Q18
Local variation of weights and priorities	Efforts were made to address local issues, such as the nature area of Amelisweerd. Interviewee 4 indicated that normally, this post would be insignificant to the alternatives	2	Interview 4 - Q18
Presentation of results to the public	The CBA is published and findable. The rest of the documentation is available on the project website, and not on Platform Participatie. No mention of the CBA results can be found in the policy documents. According to Interview 4, the results of the CBA report were not separately presented to the public.	2	Interview 4 - Q19
Explanation of methodology, uncertainty and choices	There is a good explanation of the CBA methodology and referencing is adequate. The second opinion of the CPB mentions some unclarity about choices for calculation numbers.	3	Interview 4 - Q19

Case 6: A7/A8 Corridor Amsterdam Hoorn

Indicator	Comparison to ideal framework	Score	Resulting Question
Boundary orientation	The project goal is to improve accessibility and improve the economic position of the region. The document also states that liveability should be maintained, but how this is brought into practice is unclear. There are mobility demand and public transport measures, which are evaluated separately from the physical infrastructure measures.	2	Interview 4 - Q15 Interview 4 - Q31
Travel time benefits and reliability benefits	The travel time benefits are calculated across different modalities. The reliability benefits are estimated at 25 per cent of the travel time. The report mentions that the multiplication of the Value of Reliability with the trip variability is more desirable, but that the model update was not available at the time. Interviewee 4 confirms this.	4	Interview 4 - Q1 Interview 4 - Q2
Infrastructure costs	These costs are based on the GPO calculation tool of Rijkswaterstaat. It includes investment and maintenance costs	4	
Accident/safety cost saving	In the direct study area, the improvement of safety in the area through infrastructure measures is assumed to outweigh the extra accidents caused by an increase in traffic. For the area without any measures, outside the immediate study area, the effects are calculated based on the increase of vehicle kilometres multiplied by a calculation number. According to Interviewee 4, this solution was more suitable than only using vehicle kilometres, since that would undervalue the safety improvements.	2	Interview 4 - Q32
Vehicle costs	These are calculated based on a longer travel distance and increased fuel costs.	3	
Wider economic impacts	These effects are mentioned and estimated at 15 per cent on a bandwidth of 0-30 per cent, after a considerable economic analysis.	3	Interview 4 - Q3
Energy consumption	According to Interviewee 4, this should be in the investment costs, but this is not verifiable and not based on a sustainability impact calculation. The effect is fundamentally underestimated in the current methodology. That is why a score of 2 is awarded.	2	Interview 4 - Q38
Resource use (Abiotic depletion)	According to Interviewee 4, this should be in the investment costs, but this is not verifiable and not based on a sustainability impact calculation. The effect is fundamentally underestimated in the current methodology. That is why a score of 2 is awarded.	2	Interview 4 - Q38
CO_2 emissions (Global Warming Potential)	These are calculated by multiplying the increase in vehicle kilometres with an increasing CO2 price per tonne. Here. Also included is a decreasing emission per kilometre value for vehicles, because of expected improvements in vehicle technology. The emissions per kilometre also decrease because of lower levels of congestion.	3	Interview 4 - Q3332
Habitat fragmentation and negative effects on species	The effects concern an increase in nitrogen deposition, where Alternative 3 performs better than the larger alternatives (4, 5, 6). Mitigation is not included in the CBA. The effects are therefore only included qualitatively	2	Interview 4 - Q22
Air pollution (acidification & health)	This is calculated based on estimating the numbers of citizens in pollution classes for the direct study area, and vehicle kilometres outside of the direct study area. The difference with the reference scenario is negligible. No monetary valuation of these pollution classes is given. The pollution as a result of the increase in vehicle kilometres is monetised.	3	

Noise pollution	This is estimated for exposed households in the study area. A multiplication of vehicle kilometres with a calculation number is used for noise pollution outside of the direct study area. The project has a positive influence compared to the reference scenario because it changes the routing decisions of vehicles.	4	
Landscape degradation has negative impacts (visually)	This is only included qualitatively in the CBA report, based on the EIA	2	
Community disruption (accessibility)	This is not mentioned in the CBA report. According to Interviewee 4, no large effects were expected, because the road already forms a barrier, and the cross-ability would not change because of the project.	1	Interview 4 - Q10
Impacts on Businesses and community services	This is not mentioned in the CBA report. Interviewee 4 indicated that costs for land acquisition, including economic potential are covered in the investment costs.	1	Interview 4 - Q11 Interview 4 - Q34
Distributive effects of the project	At the start of the document, the practitioners of the CBA report mention that it is important to map impacts for region and national and different types of stakeholders. In the report, no further information is given. Interviewee 4 indicates they did inform different municipalities about the effects for their domain but did not publish any public division.	2	Interview 4 - Q9
Occupational and community health and safety	This is not mentioned in the CBA report.	1	Interview 4 - Q12
Cultural heritage	This is only included qualitatively, based on the EIA. Alt 3 performs better than the rest.	2	Interview 4 - Q13
Life cycle thinking for all project materials	No other life cycle phases are included than the usage and investment phase.	2	Interview 4 - Q16
Lower/different discount rates for environmental effects	4.5 per cent for the whole project, without using different discount rates for external effects.	2	Interview 4 - Q17 Interview 4 - Q35
Rigorous trade-offs: present relative weights of costs and benefits	The 6 alternatives cover a wide range of different physical infrastructure measures and public transport solutions. They are presented with all effects and sensitivity analyses of costs. There are only compared to the reference scenario.	3	Interview 4 - Q15 Interview 4 - Q31
Stakeholder Involvement	This is not mentioned in the CBA report, but in the project, files can be found that a general stakeholder meeting was organised at the end to inform the public and discuss the entire assessment phase.	2	Interview 4 - Q18 Interview 4 - Q37
Local variation of weights and priorities	The focus of the project was on economic feasibility, so this was included. This was also supported by the municipalities that represented their citizens in stakeholder meetings.	2	Interview 4 - Q18 Interview 4 - Q36
Presentation of results to the public	The CBA report is available separately, but not included in the presentations to the public of the Exploratory Study. Presentations were given to municipalities, but not to the public. The Preferred Decision contains the general results of the CBA but is not split out over individual posts. Based on the CBA ratios, alternatives 3 and 5a were chosen as the Preferred Decision.	1	Interview 4 - Q37
Explanation of methodology, uncertainty and choices	The document is well-referenced, though difficult to read because of the large number of alternatives. The general explanation is short but covers the basics of the CBA methodology	3	Interview 4 - Q19

Case 7: A2 Deil - Vught

Indicator	Comparison to ideal framework	Score	Resulting question
Boundary orientation	The project goals were to improve congestion on the A2 highway, as part of the national highway network. Another boundary condition was that the local network throughput could not worsen. Legal limits apply to air and noise pollution. In the period after 2040, no further growth in the number of vehicles is assumed.	2	Interview 5 - Q1 Interview 5 - Q14 Interview 5 - Q19 Interview 5 - Q20
Travel time benefits and reliability benefits	Travel time benefits are calculated and monetised based on the trip Value of Time. The reliability benefits are based on the Value of Reliability and a reliability index from the model. The value of reliability is not provided in the report.	4	Interview 3 - Q1 Interview 5 - Q2
Infrastructure costs	The infrastructure costs are based on Rijkswaterstaat calculations for investment, maintenance, and preliminary replacement of structures. It is unclear whether residual value calculations are included in this calculation.	3	Interview 5 - Q11
Accident/safety cost saving	Based on expected accidents with injury, and probabilistic division of deadly and injured people, multiplied by costs per type of injury	4	
Vehicle costs	The higher travel distance leads to increased costs. The costs per kilometre are not given, also not in the direct source.	3	
Wider economic impacts	These effects are estimated to be 5 per cent of the travel time benefits from a bandwidth of 0-30 per cent. A reference is based on the EIA report, but this does not cover an economic analysis of why this value was chosen. Interviewee 3 indicated it is based on other reports and Interviewee 5 indicated that it is based on expert judgement.	3	Interview 3 - Q2 Interview 5 - Q3
Energy consumption	This is not mentioned in the CBA report, but it is mentioned in the EIA. These effects are not qualitatively reported in the CBA report. Interviewee 5 indicated that there is a risk of double counting since the CO2 emissions from DuboCalc analysis (Life Cycle Assessment) already cover energy usage.	2	Interview 3 - Q3 Interview 5 - Q4
Resource use (Abiotic depletion)	This is not mentioned in the CBA report, but it is mentioned in the EIA. These effects are not qualitatively reported in the CBA report. Interviewee 5 indicated that there is a risk of double counting since the investment costs already cover material use and external effects in the production of materials and construction process. This is a sustainability impact assessment, but not of abiotic depletion.	3	Interview 3 - Q3 Interview 5 - Q4
CO_2 emissions (Global Warming Potential)	CO2 emissions are calculated for cradle-to-grave, without including residual value or end-of-life processes. Noteworthy is that the Rijkswaterstaat tool DuboCalc was used to estimate external emissions during the production of materials and the construction of the alternatives. These CO2 emissions are multiplied by an increasing CO2 price.	4	Interview 5 - Q5 Interview 5 - Q6 Interview 5 - Q13
Habitat fragmentation and negative effects on species	This is only included qualitatively in the CBA report, based on the EIA.	2	Interview 3 - Q3 Interview 5 - Q9
Air pollution (acidification & health)	This is deemed not relevant in the EIA since only five per cent of households are exposed to a higher pollution class. In the EIA, the WHO norms are included. No quantitative assessment of air pollution is given in the CBA report, not even based on a multiplication of vehicle kilometres with a calculation number.	2	Interview 3 - Q3 Interview 5 - Q7 Interview 5 - Q16

Noise pollution	This is deemed not relevant in the EIA since less than 5 per cent of influenced households experience pollution of a higher class than before. The limit for consideration is put at 50 dB, which is higher than the WHO norms. There is no quantitative inclusion of noise pollution in the CBA report, not even based on a multiplication of vehicle kilometres with a calculation number	2	Interview 3 - Q3 Interview 5 - Q7 Interview 5 - Q8, Q16
Landscape degradation (visually)	This is mentioned qualitatively in the CBA report, based on the EIA.	2	Interview 3 - Q3
Community disruption (accessibility)	Cross-ability is not mentioned in the CBA report. Nuisance during the construction is mentioned but deemed unimportant. Interviewee 5 mentioned that positive effects were expected for cyclists crossing the Maas River. There was no data to estimate the effects.	2	Interview 5 - Q12
Impacts on Businesses and community services	This is mentioned qualitatively in the CBA report, based on the EIA. According to Interview 5, the land acquisition costs are included in the investment costs.	2	Interview 3 - Q5
Distributive effects of the project	This was not included in the CBA report, but Interviewee 5 did mention that local municipalities were informed of the costs and effects that apply to their region	1	Interview 5 - Q10
Occupational & community health and safety	This is not mentioned in the CBA.	1	
Cultural heritage	This is included qualitatively in the CBA, based on the EIA	2	
Cradle-to-cradle life cycle thinking for all project materials	This CBA contains more life cycle phases of physical infrastructure than other CBAs. It has a life cycle analysis for the emissions of CO2, but not for other external effects. This combined with the increasing price of CO2 results in a large post for CO2 emissions.	3	Interview 5 - Q13
Lower/different discount rates for environmental effects	Discount rates are shown and differ. Most effects are done with 4.5 per cent while external effects use 3 per cent. Permanent nature has a discount rate of 2 per cent instead of 3 per cent. The report includes a sensitivity analysis of updated discount rates (2020)	4	Interview 3 - Q4
Rigorous trade-offs: present relative weights of costs and benefits	All alternatives are presented relative to the reference scenario with sensitivity analyses. A large number of alternatives were included.	3	Interview 5 - Q1 Interview 5 - Q14
Stakeholder Involvement	There is no mention of this in the CBA report. There is a participation report for the Exploratory Study. From Interview 5 it can be derived that a large number of stakeholders and organisations were informed and consulted for the whole exploratory study, but not focused on the CBA.	3	Interview 5 - Q1 Interview 5 - Q18 Interview 5 - Q20
Local variation of weights and priorities	The CBA does not mention local priorities specifically, although attention has been given to local problems in the villages near the A2. Interview 5 mentioned the high involvement of local municipalities and the effects of the project on them.	2	Interview 5 - Q1, Q15,Q16
Presentation of results to the public	The documentation is online and easy to find. No specific presentation is focused on the CBA and its calculation. The Interviewees also corroborated that they did not present the CBA to any publicly interested parties, only to the client and important stakeholders. The CBA ratios and a summary table are provided in the Preferred Decision	2	Interview 3 - Q7 Interview 5 - Q17, Q18, Q19, Q20
Explanation of methodology, uncertainty and choices	There is a basic explanation of the CBA methodology, focusing on key characteristics. The calculation numbers are all provided directly in the document and are transparent. The referencing to the EIA is proper too.	3	Interview 3 - Q6 Interview 5 - Q17 ,Q19, Q20

Case 8: N35 Nijverdal - Wierden

Indicator	Comparison to ideal framework	Score
Boundary orientation	The boundary conditions were to improve the capacity of the N35 to account for future congestion and to improve the safety of the road. Of course, the legal limits for noise and air pollution are applied. The budget was 123 mln euros.	2
Travel time benefits and reliability benefits	The travel time benefits are given per alternatives, but the calculation numbers or increase in vehicle kilometres are not provided either. Reliability is given but not given how it is calculated	3
Infrastructure costs	This is calculated using the SSK-2010 tool of Rijkswaterstaat. It includes investment and maintenance costs for both alternatives with their variants	3
Accident/safety cost saving	This is calculated using the number of avoided accidents in different categories. These are provided and valued separately with calculation numbers per category of injury	4
Vehicle costs	These are calculated and monetised based on fuel costs, but the calculation numbers are not provided	3
Wider economic impacts	This is not mentioned in the CBA report	1
Energy consumption	This is not mentioned in the CBA report	1
Resource use (Abiotic depletion)	This is not mentioned in the CBA report	1
CO_2 emissions (Global Warming Potential)	This is not mentioned in the CBA report	1
Habitat fragmentation and negative effects on species	This is not mentioned in the CBA report, even though the Exploratory Study shows large negative effects on nature, but these are not included	1
Air pollution (acidification & health)	This is not mentioned in the CBA report	1
Noise pollution	Concerning the reference scenario the effect of the project is positive. The hindrance class is estimated per household. How it is calculated is unclear.	3
Landscape degradation has negative impacts (visually)	This is not mentioned in the CBA report, even though separate grade intersections should improve the cross-ability.	1
Community disruption (accessibility)	This is not mentioned in the CBA report	1
Impacts on Businesses and community services	This is not mentioned in the CBA report	1
Distributive effects of the project	This is not mentioned in the CBA report	1
Occupational & community health and safety	This is not mentioned in the CBA report	1
Cultural heritage	This is not mentioned in the CBA report	1
Life cycle thinking for all project materials	Focused on investment and maintenance.	2
Different discount rates	The discount rate is not mentioned	1
Rigorous trade-offs	Everything is represented in relation to the reference scenario. The trade-offs for variant	2
Stakeholder Involvement	The Exploratory Study mentions a large participatory process, but no specific input for the CBA	2
Local variation of weights and priorities	Safety is monetised which is one of the main goals of the project. For the rest, no local attention can be seen. A large participatory process was held, but the Exploratory Study was not focused on CBA.	2
Presentation of results to the public	The CBA is part of the Exploratory Study report and not published separately. The CBA ratios are shown as plusses and minuses in the EIA s	2
Explanation of methodology, uncertainty and choices	A basic explanation of the CBA methodology and included effects are provided. The referencing and sourcing for calculation numbers and methodologies are insufficient	1

Expertise of Interviewees

Interviewee	Expertise & Involvement
1	Senior advisor at Antea Group, project leader on multiple MIRT Exploratory Studies and Plan Detailing Studies. (Researchers notes)
2	Senior advisor at RIGO experienced CBA executor and developer of the CBA methodology in the Netherlands (Researchers notes)
3	Started working independently in 2021 after having worked for Panteia for a long time. I worked on international projects mostly, for instance for the European Commission. Through a colleague of mine at Panteia I got involved with the A2 project, but I only did the calculation.
4	Senior advisor at Decisio. My background is in economics, started 15 years ago and have now done over 50 CBAs, of which quite some are in infrastructure. I and my colleague lead all CBAs at Decisio, I was involved with the A27 as an advisor and on the other two projects I was the project leader. In the Netherlands, I am one of the experts on the CBA in Exploratory Studies
5	Senior advisor at Panteia. I am often involved in Exploratory Studies for transport projects and in the development of traffic models. For the A2 Deil - Vught, I was involved in the traffic studies and the CBA.

Question & Reponses - Interview 1

1. In the cases, I researched the goals are traffic-related (congestion, safety), but with the N65 it was specifically liveability. Are there also general broader limitations, or is it just the project goal that is important?
    - We do analyse integrally, but I would not call it limitations. We start with there is a problem with congestion, but if we are going to solve that, we also want to evaluate some sustainability impacts. Whether that is an actual goal or more of an added benefit I leave it up to you.

2. Can you describe the problem analysis in the Exploratory Study?
    - There is already a problem analysis before the Exploratory Starts. We check whether we agree and where we need to deepen the analysis. We determine the scope and the knowledge that we have to gather. The Decision to Start already has a problem analysis. In the problem analysis, we determine the goals for the Exploratory Study.

3. If hypothetically, there is only one alternative that solves the congestion problem, that will be chosen, correct?
    - Yes, I do not think sustainability (duurzaamheid, so more ecology) will ever determine the Preferred Decision, but it does lead to extra measures being taken to adjust the Preferred Decision.

4. But then you do leave out whether solving the congestion problem would be sustainable?
    - Yes. We do however also do sustainable mobility measures, so then you're talking about additional bikes, public transport and Smart Mobility projects. One thing you do have to wonder about is whether those measures are taken because of sustainability or because then we have to construct fewer measures, less concrete and asphalt.

5. There is a participatory process, and you can send in Views. If there is a group of citizens that would like to see sound be calculated on a house level, can you still do that and is it done as a result of their plea?
    - You can always focus on things that come from the Views, it would be stupid to not provide the information if it's necessary, but the government (Rijk) usually does not want that, they say just stick to the legal limitations. If you look at the WHO limitations, the government will say that's not the legal framework, so they don't bother. I think it would be better to research it anyway because you can always still discard it in decision-making, but then at least you know. If citizens say, we don't want any more noise pollution, I can only research it, I cannot promise there will not be more noise pollution. In some projects, we did that, like the A4, which gave us a lot of problems. In another project, they strived for a net zero effect on the environment, which made it very difficult

6. The budget is predetermined, correct? If you find a more expensive alternative, is that still viable?

- We can always evaluate more expensive alternatives, we did it in A58 Tilburg-Breda and with the A67 too and with the N65. You can look at the minimum, which is most of the time what the budget is based on. We always add an extra alternative that does everything perfectly but is also expensive. In the A67 that was maximum widening, but it is not often chosen as the Preferred Alternative.

7. Is that also to create a middle ground between two outer alternatives?
   - I cannot do more than give information. If you want to spend 100 mln euros, this is it, but if you have 400 mln then you have the perfect project. If the 100 mln is close to the budget then it will never become 400 mln. 110 mln is possible. Only when the safety is really problematic, you can see a real scope change, such as with the A4

8. Can location-specific priority be given to the level of detail in an analysis? For instance, nature research into protected species or economic development in poor regions
   - We provide information, if the problem analysis mentions this, then we can do it in the EIA and the CBA. What value is attributed to it in decision-making is a political thing. We give the information, and the decision-makers have to decide what they want to do with that. I do not support a multi-criteria approach where you attribute extra value to things in the EIA. We of course support the decision makers in what effects are significant and which are not. If one alternative is really good, achieves the goals and is cheap then I can write down that it is almost certain that this should be the Preferred Track. If it's expensive and goals are achieved or cheap and fewer goals are achieved, it becomes a political choice.

9. How large is the influence of the reference scenario?
   - I think the influence in our analysis is not too big, but I cannot prove that the alternatives always perform significantly differently from the reference scenario.
   - It is difficult to explain to citizens that the nuisance goes down 20 per cent compared to a situation where the nuisance gets 30 per cent more. In the CBA ratios that does not play a role.

10. The discount rate is determined by the Werkgroep Discontovoet. Are there any deviations to see the influence?
    - Yes, that is the sensitivity analysis. It doesn't play a big role, because we just add whatever is the latest number and that's it.

11. Do you have an opinion on which discount rate is better, low versus high? Because from a sustainability point of view, low discount rates for external effects are better?
    - I have no opinion on that. I like your idea, but I question what the impact would be. We do not say a lot about climate adaptation for instance.

12. Are nitrogen emissions included in the assessment phase and is it valued in the CBA?
    - Then I must dig, because I do not know the details of the CBA manual on this. I think they are a PM-post, describe the effect and consider in the final table, but there is no quantitative score or monetisation. There is a percentage included in the investment costs for compensatory nature measures. Acquisition of nitrogen emissions, in terms of land, from a farmer, would also be covered under the investment costs. The questions are also about how much information you gather can on that in the Exploratory Study and how specific your measures should be.

13. What determines whether you use vehicle kilometres or a house-level approach? Difference between the A67, A20 and the N65.
    - The N65 was done for liveability so that's where we had to get our benefits. The manual says that you can work with kilometres, so if it's not that important we use that. The problem analysis determined a different approach with the N65.

14. The sustainability problem focuses on the life cycle effects, for instance, the emissions during the production and transport of concrete and asphalt. That is not included in the vehicle kilometres. How do you deal with that?

- We do it more now, in the EIA we also determine the CO2 emissions during construction and production. We did it in Corridor A7/A8 Amsterdam Hoorn (NOTE: not verifiable) and in the A4, with the A67 we didn't do it. You have to ask yourself what the impact is.
- Maintenance and operation are included and usually, we include full replacement after 100 years, but the costs are discounted (NOTE: this is only about financial effects). If you compare two alternatives where one has a bridge that has to be replaced in 100 years and the other one does not, that is a life cycle effect, but only in cost, not in CO2

15. Do you think the life cycle impacts of projects on CO2 would lead to different results?
    - If you use it to just assess your alternatives, no difference will be seen, you also need to design for that assessment

16. For the A20. Alt 2 was abandoned and there was a lot of resistance to it from Gouda because it worsens the economic situation in Gouda. How was this decision made?
    - I have to dig for that we only did it based on increased local traffic and not the economic impact.

17. The induced demand is included, right?
    - Yes, it is in the traffic models we use

18. Do you do anything with the CBA results? Is there someone present at the information evening of the Preferred Track to explain the CBA results?
    - The CBA is on its track. It just has to be done because it is required. Sometimes I can put in the CBA ratios in the EIA with 1 or 2 small sections. Sometimes it's an appendix, such as noise and air pollution reports. The separate presentation of the CBA I have never seen. It takes an internal route and then goes by the Parliament to be approved quickly. If you look online, you are not going to find it for some projects. Sometimes some questions are asked about the CBA and why the ratios are low, but then we just explain that, and no further questions are asked, such as with the N65.

19. In the end, the public meeting is only informative, right?
    - Everyone wants to know what is going to happen, not the CBA results. Citizens are not interested in the CBA, except if they are against the project and the ratio is negative. For nitrogen, you can go to court, for the CBA there is no legal basis. If you have 10 alternatives and you want to continue with a negative one, that is okay, as long as you explain why.

20. For the N65. How is the term level of barrier obstruction monetised?
    - We had a lot of discussion about that, but we interpreted it with the cross-ability of the road. A lot of current intersections would disappear, but separate-grade intersections would come back. With the knowledge I have now, I would have focused on cyclists and pedestrians because now we are still really focused on improved travel time for cars.

21. With the road you cut a road into two basically, that is barrier obstruction, with affects the accessibility of local communities
    - Well, the N65 was already there, so that is a difference. The barrier obstruction does not change that much, you really have to look for the benefits.

22. For the N65, you measured spatial quality for car drivers, how did you arrive at those numbers?
    - The guidelines only mention use value, future value and experience. Numbers I determined with a landscape architect.

23. The spatial quality was also valued by hedonic analysis of housing prices, with a 20 per cent value increase for free view. How was this done?
    - This is really from the CBA firm (NOTE: RIGO). We gave them a note and they found this method for it.

24. How much research is done into which effects are relevant? You have decided which effects to take into account, but what determines the level of detail in the analysis? For instance, it is important to assess noise pollution, but we can do that at individual house level or we do a general approach using vehicle kilometres.
    - That is always difficult. You now mentioned specifically the CBA, but that is the case in the entire Exploratory Study and the EIA. You have this process of what should I analyse at what level. I would like to be more pragmatic and have more freedom to decide, but from risk analysis, consistency Rijkswaterstaat has the manual for Exploratory Studies and for a lot of items everything is determined in a lot of detail, which is not good for real exploratory research. Sometimes there is a difference in scope for the EIA and the CBA and the question becomes whether you can just use the EIA research for the CBA or whether you need to use a different study or method as input. I cannot say how that decision is made.

25. How are the alternatives determined?
    - The consultancy firm has the lead, based on analyses of relevant criteria. In the A67, there are traffic simulations. What you're going to analyse is based on the problem analysis. What are we trying to solve? When we have the answer, we generally create a series of increasingly bigger alternatives

26. About the A67, Smart Mobility measures were specifically chosen as a solution, how much can be achieved with that?
    - Our clients were Smartwayz. So, there was a goal to do something with sustainability and Smart Mobility. I think that is good to determine whether you need additional asphalt or that you could also fix the problem without that asphalt. I now do that in other exploratory studies as well. What can we achieve, without any physical interventions?

27. Is any attention spent in the analytical phase, on which effects will be analysed in the assessment phase?
    - The basis is already in the assignment, the problem analysis, you HAVE to take these things into account. But you do have to detail that assignment and then you adjust your assessment framework to that.

28. About the A67. The Preferred Track solves the point where all the accidents happen, but the number of accidents grows because of the growing traffic. Why?
    - We had a lot of discussion about that message because we make it safer, but it becomes more unsafe, but elsewhere. At the A58 we had the same thing, you put an extra lane, so you assume that it is safer, but there is also 30 per cent more traffic.

29. This is a hypothesis. More vehicles lead to more accidents. Do you account for the changing road design there?
    - Not in the projects, but in the CBA the calculation number differ per road type and I/C number. That's what we take into account. The specific road section might be safer, but the total network is not.

30. About the A67: Was it difficult to take into account the Smart Mobility measures?
    - No that was relatively simple. If you have some experts, you can easily implement it, we also do it for other projects.

31. For some effects, no impact on either intensity or capacity of the road was expected. Were decision-makers disappointed about this?
    - The expectations are high, but if you look at the studies it does not do too much in the bigger picture. Maybe you reduce the number of vehicles to about 100, but induced demand and autonomous growth add a lot of extra vehicles.

32. Are demand-focused measures difficult to analyse and assess?
    - With a bunch of assumptions, it is easy to do, but the expectations are too high

33. In the end, everything is put into the CB ratio. Do the decision-makers ask where the numbers come from? Or do they focus on their interests?
    - Specialists focus on their theme always, but in the end, very little actually gets to the decision-maker. If the ratios in a CBA are positive, you get very few questions, since it confirms what they want.

34. Do you think the life cycle impacts of projects on CO2 would lead to different results?
    - If you use it to just assess your alternatives, no difference will be seen, you also need to design for that assessment.

Question & Reponses - Interview 2

1. Is the assumption always made that traffic would grow with a yearly percentage? Is this percentage based on the WLO scenarios of the PBL?
   - Yes. Indeed, it's based on WLO. Maybe that is all wrong, with all sustainability goals and policies they should maybe be changed. But for consistency in assessing investment decisions, it is nice to work with one set of scenarios. The MIRT has a lot of projects, and the standards need to be the same, but with the developments, the growth may be less.

2. The growth of traffic in the N65 is limited to 2050, why?
   - We were afraid that we should not make any assumptions about something that is so far away. I think that is logical

3. Are local developments included in those scenarios? For instance, local neighbourhoods are being developed or an infrastructure investment focusing on industrial developments.
   - Spatial developments may be predicted. If the PBL or RIVM determined large spatial developments that the scenarios are based on. In the project though, the local spatial developments as a result of the project are not explicitly included. Spatial developments that are already underway when the CBA is performed are included. In local developments, we calculate it with regional models, different from the national model.

4. With a lot of projects, the total number of vehicle kilometres does not change in comparison to the reference scenario. Is that because there is only a move from local roads to highways?
   - You work with regional models. Traffic that formerly used different routes now goes to the highway. In totality, the number of vehicles does not change that much compared to the reference scenario.

5. In the reference scenario, you assume an autonomous growth of vehicles. What do you actually compare?
   - The difference between alternatives and the reference scenario is not large, because both of them have the same number of vehicle kilometres. CBA is an analysis of the differences. You try to determine the performance of an investment on all these indicators. If through the years, the increase in mobility causes all kinds of harm to noise or pollution, this is not reflected, since the CBA only looks at the investment's performance.

6. You could build extra noise barriers, to alleviate the autonomous growth of noise pollution.
   - Yes, you could do that. If your alternative consists of a noise barrier and an extra lane, an improvement compared to the reference scenario is possible. You can ask the question whether I should not always consider the impeding negative effects, but that is usually congestion, not noise or sound.

7. Should you present the reference scenario in the final tables? It would show that the congestion would of course happen in the reference scenario, but also that the noise and air pollution would also go up.
   - That is also done, most of the time. The urgency is the problem analysis, it would be nice to show all the negative effects. That is always done for congestion, but I don't know if that is also done for external effects. A question from me to you: does your analysis of the cases show that we do mention the autonomous congestions (answer: yes) okay then I agree with your stance that we should also show the other development.
   - A critical note on the N65 CBA and the inclusion of local interests is that a neutral analysis was not appreciated. They already wanted a tunnel, which became the goal. If you want to include local effects in the reference scenario, as the problem analysis, local interests should not overpower consistency in the analysis.

8. What I read is that the general travel time calculations are done well in the Netherlands. For the A67 specifically, was it difficult to include those in the model? I read assumptions were made to determine the demand decrease for vehicles. The executor from Antea Group said they were easy to implement
   - I worked in the back on this, with my colleague in front. We kind of assumed the goals of the Smart Mobility measures would be achieved, without a model analysis. Smart Mobility measures are, I think, wishful thinking

9. Are the travel time costs of construction for road users calculated?

- No this is not included unless it is specifically mentioned as part of the problem analysis. I can remember that it was a part of the A10 Amsterdam Zuid project. It was shown that the cost of constructing everything underground for 15 years was not worth it, in terms of travel time.

10. In all three cases, the investment costs are described as calculated by Rijkswaterstaat. So how is it done? Is it only a calculation of unit prices per road or concrete, or do they include construction, labour and materials?
    - I do not know the ins and outs; you should find somebody who does those calculations. There is a standardized methodology, and I cannot imagine that labour costs are not included. They also have all kinds of risk buffers.

11. Should the CO2 -emission calculation not include the effects that occur during the life cycle of the road, such as the production of materials?
    - Yes, we should do this. We do not do anything with life cycle effects. We do not include the cars that drive on the road, and we do not include how they are made. We should have a standardized way to make this, with a unit calculation number.

12. For safety, in all three cases, the vehicle numbers are multiplied with calculation numbers. At the N65 and A67 traffic safety was an important factor. Why is this not done with a probability of accident analysis and cost per accident?
    - I would advise keeping to the calculation numbers as much as possible if you can do it with vehicle kilometres. In the A67, the specific section that was changed did have an improvement on accidents, but the other sections did not change. This was included as a PM-post, but in comparison to the growth of the number of cars, it is negligible.

13. For the N35, they did calculate the safety benefits in preventing deadly accidents, with a benefit in the order of a couple of million. Is this not a better method?
    - If that is the goal of the project, and if it's a large effect, consistency needs to be maintained. You are spending the same taxpayer money every time. If you change the methodology every once in a while, that is okay, but you should not deviate from the standard per project.

14. Should you, if you design a new intersection, with an A67, assume that all accidents are prevented and we avoid this much damage, since other intersections that are designed like this also matter?
    - I would support that, and if I am thinking freely, I would say you base it on vehicle kilometres and then calculate the benefit of solving the intersection, if that is large enough then you can include it. You should maybe also include the congestion alleviation of the prevention of accidents.

15. In all three cases, the wider economic impacts are not mentioned or not applicable. Why is this the case, since every road is expected to have economic benefits as a result?
    - In the 1990s, we decided that the efficiency, spill-over effects and agglomeration effects are not important, since most of the companies already exist and already operated together. The travel time benefits are the most direct economic benefit. We assume it is a balance that is shifting, and not extra developments, on top of the travel time benefits.

16. In the EIA, for the A20, energy consumption is mentioned. Alt. 3 used 1.5 -2.5 more energy than Alt.1 because it has extra asphalt, in the construction phase. In the usage phase, it is the same. Why is this not included in the CBA?
    - This should be included in the life cycle of the construction. In the usage phase, it should not matter that much. Fuel costs are in the vehicle costs, but lighting is not. The energy consumption of the alternatives is in the investment costs, but the external effects of energy consumption are not.

17. Do the market prices of construction materials and energy prices cover the external effects of extraction and production? Shouldn't they be monetised with an extra margin for these effects, so that sustainable asphalt performs better than unsustainable asphalt? In the market price, unsustainable asphalt is usually cheaper.
    - We need to do more with life cycle impacts

18. CO2 -emissions, are not included in the N65 and are only calculated with calculation numbers and it is not calculated in the N65.
    - I cannot imagine that we didn't calculate them for the N65, but the calculation numbers are not up to date anymore. (NOTE: the second opinion of the KiM did mention CO2 emissions were not included, but in the calculation number that RIGO used, CO2 is covered as well).

19. Effects on nature are not mentioned in the CBAs of the cases, even though the EIA mentions serious effects on protected species and Natura2000 areas. Should the costs for mitigation not be included, not even considering the welfare effects these places have?
    - Now with the nitrogen, I think this should be important. At the time, there were definitely methods and calculation numbers, but we did not include them, the outcomes were too small. The alternatives are leading. You should predict the impact of life cycle impacts, and whether it leads to significantly different outcomes.

20. Air quality is calculated by multiplying the vehicle kilometres with calculation numbers. Is this a proper approach to consider the local (health) effects for the people adjacent to the road?
    - You need to check the CE Delft report. I cannot say whether the calculation numbers specifically cover the health costs for local people

21. Noise pollution is also calculated using calculation numbers and vehicle kilometres. Is this an acceptable way of estimating the damage to localised noise emissions?
    - I think the models to estimate this is always about localised emissions and effects, so I think we have that covered. The calculation numbers do reflect this.

22. Why not include the benefits of the National Noise Alleviation Programme in the benefits of the N65? The main benefit of grade-separated roads is noise alleviation, but now that was already done in the reference scenario
    - We had to do that because the reference scenario assumes all irreversible policies. The effects of the noise would not have changed the outcome of the CBA.

23. Landscape degradation, or improvement, was a major part of the N65. Was your approach to housing prices proper? Should this also be used for other projects?
    - There were not that many houses, so it was relatively easy. But the effect, in the end, was small

24. Should the health effects of a nuisance during construction not be quantified and monetised?
    - I wonder whether this results in a difference between the alternatives. The main goal till now has been whether it's socially responsible. Now we also want to include sustainability. It would be nice to see the possible improvements and have some examples of the effect.

25. Are the societal costs of construction accidents included? What if the labour conditions in foreign countries would be included?
    - This would not make a difference, because the construction worker would also have the same risk in another project. We do not see it as a welfare effect, in the balance of effects. I think we should include labour conditions in other countries, in so far that that is the case. But the life of a person in Africa might be worth less than someone in Europe. That is an ethical question.

26. Should projects with uneven distribution of costs and benefits have a negative score compared to those that are more equalitarian? The biggest difference is between road users and residents.
    - No, we assume Pareto-efficiency, so there are winners and losers, where the winners should be able to compensate the losers. The winners should normally compensate the losers, but they don't have to.

27. With the N65 the benefits and costs are divided among the government, citizens and road users. Should this not be done for each project?
    - Yes, and I have done it, it helps in the negotiation process, serves as a basis for compensation

28. Is it included in the CBA methodology? Not considering the welfare value of cultural heritage are costs of archaeological research included. Should those not be included in the analysis? Or the delay they could cause to the project?
    - It's included when it's relevant. In the manual, it says to include it qualitatively because the impacts would not be big enough.

29. In the numbers from the Werkgroep Discontovoet the baseline is 4.5 per cent but for external effects, it is 2 per cent. Was this applied in the cases? It is only explicitly named in the A67, but in the A20 and N65, it is not mentioned.
    - Yes, we apply this, and there is always discussion about these numbers so in the future it will be updated again. (NOTE: in the answer from the interviewee, it is not explicit whether these numbers were also used in the A20 and N65)

30. Should the effects of the reference scenario not be presented as a standalone alternative?
    - Yes, this is sometimes done, and I think it is good to do this.

31. Is there room in the CBA for local inputs from stakeholders and the environment to determine which effects should be estimated on which level of detail? Would such influence help to lower the Blackbox effect of the CBA?
    - In the N65 there was a real discussion with the residents. I can of course explain how it works, but the local interest is so big, that you really need a psychologist or communicator to make people understand. I can explain it to you and other scientifically literate people.

32. Was it difficult for the N65 to focus on liveability instead of congestion?
    - I can remember that we had a lot of meetings to try to inform people. Only one project we really succeeded in North Holland, about peat nature areas North of Amsterdam. We had input for what you think is important, which we used for the methodology. It is difficult to include people in the methodology when they have already taken a stance.

33. Do you think the Dutch CBA methodology is transparent and understandable?
    - My experience is that people find it a black box. Even specialists have difficulty understanding it. If you are not a CBA expert, it is difficult to understand. It is however consistent and useful for assessing investment decisions.

34. Is that because of the CBA methodology and the process? Or is it just technical?
    - It is economic thinking and that's difficult. Once people take a stance, they are scared the tool will out rule their position. They feel their interests are not considered and are diminished. I think the CBA takes absolute ideological points and makes them comparable

35. Would it be useful to include a standard list of effects that should be named and assessed, and at least mention that no effects are expected?
    - Yes, I think this would be useful. You get problems that it does not cover 'local' interests.

36. The CBA is usually not presented separately, more as an annexe to the EIA and the Preferred Decision. Would it be good for the CBA methodology to be presented separately? For its understanding?
    - People have learned that the EIA is part of the process, even though it's quite technical as well. The EIA covers all effects, and the CBA adds a comparison. It would take a lot of work to convince and make everyone understand the CBA methodology. It would be nice to have a general explanation of the CBA methodology somewhere in the process

37. This is not explicitly mentioned in the CBA. Is this normal? Should the local negative effects not be included?
    - This is included in the normal travel time benefits, but it is included as one item on the CBA.

Question & Reponses - Interview 3

1. How were the reliability benefits calculated?
   - I just got that from the model immediately, I was not responsible for the inputs. The others did that. I just updated the pricing from 2014 to 2021 with an index.

2. How were the indirect economic benefits estimated?
   - I checked a few CBA reports and used that as a guideline. I took 5 per cent since the road already exists and it's just a capacity increase.

3. Why are all the environmental criteria included qualitatively, except for CO2?
   - For ecological effects, I just took everything from the EIA, since it was not estimated quantitatively. The CO2 prices come from Rijkswaterstaat. It increases.

4. You used different discount rates, from my ideal framework, it can be determined it is good to have different discount rates.
   - Yes, I got that from Rijkswaterstaat.

5. Why was the value loss of land use not monetised?
   - I just got it like that from the EIA.

6. All calculation numbers are present in the main report, why is that?
   - Well, I looked up some old reports and found that annoying to read, so I did it this way. Also, Rijkswaterstaat demands that they can always get my sheets and check everything. Maybe they do it on purpose so only they can calculate it.

7. Have you ever been asked to explain the document at the client or in other public meetings?
   - Yes, we had meetings with Rijkswaterstaat and Witteveen+Bos to discuss the results and the process, but not at a public meeting.

Question & Reponses - Interview 4

1. Why did you only estimate the costs of travel time during realisation qualitatively? Is that a fair representation of the situation? Should they not be estimated quantitatively and monetised (A27, A7/A8 and A58)
   - In principle, I think you must take those effects into account. However, the policy question is what the long-term effect is, and a lot of measures are taken during the realisation to alleviate the congestion. That is often a boundary condition, and all those costs for prevention are included in the investments. In the project not far from here A10 Zuidasdok, the measures for alleviation are almost as costly as the actual improvements themselves and the engineers have become very good at alleviation.
   - You also need to make things consistent. Maybe we do not know what the realisation is actually going to look like, so it’s difficult to estimate the effects reliably. We did do some worst-case scenario studies, for instance, if the tunnel of the A10 is flooded, but not in the main analysis.

2. Travel time reliability benefits are estimated at 25 per cent. Why 25 per cent? (A27, A7/A8 and A58)
   - We do it differently now. Now we use the Value of Reliability multiplied by the standard deviation of average travel time and then multiply that by the number of trips taken. At the time of these studies, the models were not advanced enough for this.
   - In hindsight, 25 per cent was a good estimate. It was based on a 2000s study carried out by the KiM

3. The post for indirect economic benefits is valued at 15 per cent. Why? (A27, A58 and A7/A8)

- This is done in the same way. There are guidelines from the PBL and KiM. We also did our own research into this, and we arrived, through economic analysis, at a bandwidth of 0-30 per cent. If you do not have a good reason to assume it is zero, but also no good reason to assume it is 30, we take 15. You can analyse the economic structure, and look at unemployment differences between regions, are those averages or do they differ?
- At the Ring Utrecht, we took 15 because it's a road of national importance for all kinds of traffic. In the end, we do look from a national perspective.

4. In the report, you mention that you compensate the two hectares of lost EHS nature with 5 hectares of new nature area. How did you achieve this number? (A27)
    - Well, we were advised by environmental experts that to compensate two hectares of full-grown nature you need around double the amount to compensate. There is a little bit of overcompensation in this case. This would compensate for the ecological value.
    - NOTE: in the document it says 2^{30}, which indicates a footnote for sourcing not 'to the power of'

5. For the replanting of trees, you calculate 150.000 euros per year, and over 70 years that total discounted value is 1.5 million, which is rather small on the total project cost. Why was the recreational value of the trees not estimated? (A27)
    - We had a lot of discussion about this. It was very sensitive and normally we would not even look at this and just write it off as insignificant. There was a lot of resistance from residents on the one hand and the client was very specific about the new access route that was created. This basically
    - You mention the travel cost method from the guidelines for nature assessment. It is not really applicable here, because it does not measure the specific value of the trees we are removing, but rather of the whole nature area. So, I do not think the travel cost method is a good approach. The improved access to the tunnel to get to the park is also part of the project, so that would make the accessibility better.

6. The emissions for CO2 are calculated based on the additional traffic that is generated by the project. So the autonomous growth of vehicles is not included in that. (A27)
    - No, you calculated the difference between a project and a no project. We are analysing the question of whether the project is suitable. We are researching not whether population growth or immigration is desirable. You could also say that this method would make the impact of the project less important since the CO2 emissions are already growing by so much in the reference scenario.

7. How large is the influence of the continuation of neighbouring projects? For instance, the NRU is not completed yet. Should that not be in a sensitivity analysis? (A27)
    - We did do a sensitivity analysis; it should be in the report. The widening of the Northern part of the ring Utrecht, the southern part and the northern part were all included in the sensitivity analysis. It did have a large effect. If those projects did not continue the travel time benefits would have been 1/3 lower. Standard practice is to include everything that is reasonably expected to continue, and those are the projects that are in the MIRT. There are requirements for it, mainly that at least two-thirds of the budget has to be acquired. I think we have to take those into account of course, as an analyst and an external party would have told us we had to do it if we hadn't done it. The analysis does get larger and that is difficult, but it is good to do.

8. For the particulate matter emissions, no estimates were made for affected households. You only multiplied the number of increased vehicle kilometres with a calculation number. Why? (A27)
    - For particulate matter, I think the data was available, but we chose not to evaluate it because there would be double counting of costs. This has to do with the differences in the study area for the EIA and the size of the study area in the CBA.
    - It is difficult to monetise the specific localised effects of particulate matter. Methods that use QALY's or DALY's exist. It is difficult to estimate the added effects of going to a higher emission class.

9. No specific diagram was made to show the differences between the costs and benefits for the different stakeholders. (A27, A58, A7/A8)
    - That differs, we do not do it always, but after the new guidelines from the PBL regarding Brede Welvaart, it is advised to indicate the differences between different groups, regions, and generations. I expect it's going to happen more. Sometimes for local policy questions, we do it more, but usually, the CBA is done for a national policy, and we follow the existing procedures. The attention given to different effects for stakeholders is dependent on whether the local interests are relevant in whether the policy is adopted or not. For the Ring Utrecht, we evaluated the accessibility of Utrecht. 80-90 per cent of the travel time benefits area for travellers not coming from or going to Utrecht. For A7/A8 Amsterdam-Hoorn we did perform some local analyses, but the level of inclusion is limited, simply because the return is calculated from a national perspective. In the end, we do not say anything about whether the distribution is fair or unfair.

10. Was any attention given to effects on local accessibility and the cross ability (in travel time) of the road? (A27, A58, A7/A8)
    - We did address this for the A27, at Amelisweerd. The method of travel time benefits does not work because there was already a tunnel. The improvement was purely in the quality of the access to the recreational area.
    - We did address this at the N-road project at Coevoorden, where the grade separation and removal of an intersection were relevant.

11. Was any attention spent on the loss of other economic functions? (A27, A58, A7/A8)
    - We did not specifically address this except for the recreational value area of Amelisweerd
    - Compensation for the acquisition of land, which is based on the earning potential is included in the investment costs.

12. Was any attention spent on labour conditions in the production process of construction materials? (A27, A58, A7/A8)
    - No this was not done.
    - It has been done in projects, but then it is included in the investment costs. You would include a sustainability reserve in the investment to account for the difference in the price of construction materials.

13. Was any attention spent on the archaeological value of the landscape and how much would this have cost? (A27, A58, A7/A8)
    - Only qualitative, not quantitative, or monetised for Amelisweerd.
    - Archaeological research is included in the investment costs.

14. Why were only two variants considered in the A27 Utrecht CBA?
    - It was a political assignment from the Parliament to just do the Preferred Decision. I would have preferred to analyse different options and contribute more. Now it's more of a validation CBA instead of an active part of decision-making.

15. I see problems with presenting alternatives in relation to the reference scenario. That creates the impression that emissions and nuisance only get relatively worse, while the autonomous growth of mobility already has negative effects. Should the reference scenario not be presented as a separate alternative? (A27, A58, A7/A8)
    - No because you are not evaluating the desirability of the reference situation, but of the project. Then the policy question becomes different.

16. Have the external effects of the production and realisation phase of the project been calculated, and should this be done? It was done for the project A2 Deil - Vught (A27, A58, A7/A8)
    - No, we have not done this for these products. I do not know if it should be done. You first must evaluate whether it is already in the investment costs and to what extent it changes the conclusions. For instance, for CO2 the producers of those materials need to purchase CO2 rights from the emissions trading system of the EU. If they do not produce,

they can sell those rights again and somebody else will emit the CO2. The total emissions do not change. That is at least for the production costs, but not transport or construction. That only goes for CO2, not for other emissions.

17. Was a lower discount rate used for external effects than for economic effects? (A27, A58, A7/A8)
    - No this was not done. The recommendation is to discount all effects with the standard rate and to use a higher effect for congestion effects and a lower rate for investment costs.
    - There was some confusion about the guidelines for discount rates.
    - For CO2 emissions, it was decided in between that they should be discounted with a lower rate, but in the new guidelines that has been revised again.

18. Was any time spent on the evaluation of local interests and preferences? Were stakeholders involved, like clients and other interested parties? (A27, A58, A7/A8)
    - (A27) For Amelisweerd, we would have never taken into account the value of the trees, but that came from the client, we did not survey residents for instance. We toned down the involvement of citizens because the project was already so sensitive, but the political positions are clear. Specifically for a citizen organisation we also did an extra explanation of the results and the process, but that was not part of the project. They hired us.
    - In principle, all relevant effects must be included, but sometimes you miss something, and then local participation can be useful. There are also annoyances where we see double counting of effects and residents see something else and then explanation can help.

19. The calculation numbers are all given in the appendix. Is this common? Is there a specific reason for doing this? (A27)
    - Readability, we think it's important to show the effects and how we arrive at the conclusion. Everyone who wants to specifically know how we calculated everything can refer to the appendix.

20. Was the CBA separately published and presented? Or only by the Ministry? (A27)
    - I do not know precisely; we have not presented the results as part of this project. The client determines whether we present it.
21. Why were only widening and rush hour lanes considered and not wider alternatives? (A58)
    - We also evaluated 2x4 and the parallel structure in the first phase of the alternatives, but only on costs vs problem-solving. Normally the CBA only happens in phase 2, but we did a small CBA in phase 1. Sometimes our own analysis or external assessment results in extra alternatives being considered.

22. Why were effects on species and habitat not quantified and monetised? (A58, A7/A8, A27)
    - It is impossible to value specific species. There are other projects, such as a Windpark on the North Sea, where we evaluated the costs of prevention, based on changing the entire project.
    - For this project, there are EIA effects, and if there are no real red flags, the project continues. If there are red flags, the compensation is often included in the investment costs, but sometimes additional valuation is necessary.

23. Effects on Natura2000 areas are mentioned. Did methods exist to determine the costs of the compensating methods, as a means of monetisation?
    - At the time, the effects on Natura2000 effects were not relevant, because the policies were different.
    - Now you must make local costs to fix the problem locally. It could determine whether the road can be built. On the other hand, we need to show it in the CBA, but maybe there is no CBA since the road cannot be built. That is more the jurisdictional aspect.
    - We are analysing the practices of the firm Harbour of Amsterdam, where they are turning down capacity in one location to free up space in another. However, since they are not using the capacity in the first place the CBA still shows a net effect, while from a permit perspective, there is no change in output.

24. In the report, it is mentioned that preventative measures for nuisance during construction are included in the investment costs. What are those costs? (A58)

- Temporary diversions of traffic streams, informing stakeholder groups, temporary bus lines
- It is about 25 per cent of the costs
- It does not include nuisance to residents during the nuisance, in terms of noise pollution and such.

25. In the CBA report, it is mentioned that the CBAs give insight into the division of benefits and costs across groups. Why is this not done? (A58)
    - Here it apparently did not play a large role, but we do generally spend time on it. We specifically mention the effects within the project area such as EIA and the effects on a wider region. Generally, from the CBA you can extract where the costs and benefits fall onto, but if it's not a specific issue for the project, it is not a priority for the conclusion. For the A58 specifically, most residents are users of the road and are really interested in solving the congestion and not the external effects

26. Have life cycle effects been included for production and realisation? (A58)
    - No.

27. What discount rates were used? (A58)
    - The same percentage as in the other projects. (NOTE: report says otherwise, 5.5 per cent instead of 4.5)

28. Was the extra time spent on the inclusion of local interests and priorities in these projects? (A58)
    - No, not very specific in this project.

29. Were stakeholders included in the CBA process, such as clients and other stakeholders, mainly because the client is Innova58, a collaboration of local governments?
    - This was a clear national-regional collaboration but was led by a central project leader from the organisation. We were only part of the process and have had a more intense collaboration with the client.

30. Was the CBA presented to residents and interested parties, publicly?
    - No, not specifically for the CBA. Maybe it was done for the entire study during an information evening.

31. In this project, many alternatives were evaluated, including a public transport mobility management package. Is this large number common now? (A7/A8)
    - Quite common yes. As I said, in the A58, there were also 12 alternatives first. In the second phase it is usually three alternatives, sometimes more, sometimes less. I support including a mini-CBA in the early phase of the Exploratory Study to exclude alternatives. Sometimes we only enter the process at the end, and I feel that good alternatives have been left out on simplistic grounds and not our integral grounds. Sometimes we enter the process when the process has already been done. Then we find out that we do not have the correct information. In that sense, we are independent and critical of the information provided.

32. An assumption is made that the infrastructure improvements will compensate for the increase in accidents because of traffic, why? (A7/A8)
    - There was no safety analysis of the project area. We could not analyse what would happen to the same effect.
    - We know that congestion makes roads more unsafe. Some improvements to infrastructure were directly responsible for accidents previously. So here we decided to let them clear each other.
    - We could have also made a negative calculated post and had a positive PM-post for the safety improvements, but then the negative post would have been quite big, and we felt that was not a good depiction of the situation. We made it into one PM-post.

33. Is this the first time that the calculation price for CO2 goes up with time? (A7/A8)
    - Of the CBAs you are researching this is the first one. In 2015 or 2016 the call from CPB/PBL came to do this for the CO2 prices.

- It is a two-sided thing. The CO2 emissions per km also drop because of cleaner vehicles. In previous projects, we assumed those two developments would cancel each other out, implicitly

34. Are effects on loss of economic activity included? (A7/A8)
    - This is covered in the investment costs, as costs of acquisition

35. Were any different discount rates used? (A7/A8)
    - No, the 4.5 per cent

36. Was any attention given to local interests and priorities in this project? (A7/A8)
    - Yes, based on data analysis and economic analysis as a background document.

37. Was the CBA ever presented separately to interested parties and stakeholders? (A7/A8)
    - No, but we did talk to all different municipalities, they were also involved in all the advisory groups during the project. This was done because of the regional economic goals of the projects and because they were contributing financially. We talked to the municipalities of Hoorn, Zaanstad and Purmerend, so they represented local interests. The project was very important for these municipalities, but it was only interested in the companies in Amsterdam.

38. Energy usage and material usage are not included in any of the CBAs I analysed. In principle, it is covered in the investment costs, but less sustainable materials and energy are usually cheaper than sustainable alternatives. To what extent is this included in the CBA?
    - That is not done in general, but there is a significant risk of double counting. There are added taxes on fuel and electricity. There is a CO2 trading system in Europe. It will be included in the market price and otherwise, they can sell their rights again. This does not go for other external effects than CO2, such as particulate matter. For abiotic depletion, I find it difficult to say whether that is covered in the market price. There are enough places where it is not included in the market price. I think you need to first do a supply chain analysis to determine whether the market price accurately represents the impacts of the production process. I think it's a good idea to limit the environmental impact and use tools to guide that process, I cannot be against making good choices. I am not sure whether it should still play a role in these CBAs, because sustainable versus not sustainable asphalt is almost a separate CBA. It is a separate issue, it's better to make it normative, as these are our requirements. However, I think it would be good to substantiate that norm with research. You have to be smart with the allocation of resources for CO2 emissions

Question & Reponses - Interview 5

1. In contrast with other projects that I have researched, this project has 4 alternatives and one mobility management package. Do you think the 300 potential solutions and 19 viable solutions were represented correctly, with a good balance between small measures and large measures?
    - Yes, we filtered the alternatives as that is called. We did this with stakeholders, the local environment, and businesses. We examined the problems and asked for suggestions. This resulted in 300 suggestions, out of which we defined 19 solutions. This resulted in 3-4 main alternatives. It included a participatory process with 'worktables' and stakeholder meetings. In total, there were about 40 participation meetings.

2. How were the reliability benefits estimated? The report mentions the use of the value of reliability and a reliability index from the model, but there is no further explanation.
    - This is a tool from the NRM model. If you want specifics, you should ask it at Rijkswaterstaat at the Steunpunt Prognoses. I have some issues with reliability benefits since I think it is already included in the Value of Time, implicitly, but for that further academic research is necessary.

3. The indirect benefits were estimated at 5 per cent. No explanation is given in the report, how was this value determined?
    - That I do not know exactly. This is a standard methodology, and we used a standard methodology. We chose this value through expert judgement.

4. From the ideal framework, it follows that energy usage and material used should be explicitly mentioned and assessed in the CBA report. I have seen them in EIAs, but not the CBAs. They can be covered in the investment costs. In the EIA of the A2 project, it is mentioned that CO2 is a good approximation of energy use. Do you agree with that?
   - That is quite simple. It is either one or the other. One litre of diesel results in one kilogram of CO2. If you use energy consumption and CO2 emissions at the same time, you risk double counting the same impact

5. The price of CO2 goes up quickly towards 2050. Is this common for CBAs?
   - It is common. Now it is 100 euros and will go up to 2050 because it becomes increasingly more difficult to reverse climate change.

6. Because the price goes up and the emissions of realisation and production of materials it is quite a significant post. Do you see that as well, in comparison to other projects?
   - It goes up, so that is very simple. The influence on the Preferred Decision is questionable since the other benefits outweigh the negative benefits. I cannot say whether the influence is larger than other projects.

7. For sound and noise pollution no monetary valuation was given. According to the EIA, the influence on households was not significant, but this could still have been monetised for the CBA. Why was this not done?
   - From my knowledge, it is common to not include it in the CBA if it is not significant in the EIA. You should request it with Rijkswaterstaat. The monetary value of those 5 per cent is very low. I do not have specific opinions on these small values.

8. For sustainability assessment, the WHO values for air pollution are included, but for sound, this was not the case. In the EIA 50 db, is used instead of 45 db.
   - I do not know that, maybe it was not necessary. None of the experts involved said it was necessary. On the northern part of the route, there is almost no built environment anyway.

9. Large effects are estimated for Natura2000 areas, because of nitrogen emissions. A provision is given that compensatory measures are necessary, is that not monetizable?
   - That is difficult, is that monetizable? I think you should just name the effects. It is a lot of work and there is no standard methodology, so that is an invitation to the CBA community to come up with something.

10. Should the division of effects between different regions, cities and towns be given?
   - Little is said about this in the methodology. The effects are always local relative to where the road is. I think we left it at naming the effects. The effects of this project are large, traffic was taken away from the Moerdijk Bridge and the Maas Bridge on the A50. It is very difficult to accurately represent these patterns
   - Local stakeholders are always a priority, we contacted the local villages and try to compensate them. The different levels of government make this difficult. Usually, the money or political will is not there to compensate, the municipalities. The national government can only compensate for the legal framework that applies to their road.

11. Why is the loss of land use functions not being monetised?
   - That should be in the investment costs, such as the acquisition of land and compensation for loss of economic value.

12. The barrier function was only assessed qualitatively. At the N65 the analysis contained travel times over the road. Would that have been a good method here?
   - No, the road is already there, and it does not change. The N65 is a different type of road.
   - At the Maas there would be some possible travel time effects, we did not have the data or cycling counting necessary to calculate the benefits.

13. The emissions during the realisation and production of the project were calculated with a tool called DuboCalc. In relation to the reference scenario the influence is quite big, but not in relation to the base year, if you discard the autonomous growth of vehicles.
    - I do not think the effect is negligible, but it is a difficult topic since you also are evaluating over a period of 100 years. I do not know if the development of vehicles is included in the model that we used for this calculation.

14. Should the reference scenario be presented as a separate alternative?
    - Yes, I think you should always have a reference and it's good to show it. We are now doing a study for Europe and here we show the reference scenario. It is not important how you get from the base situation to the reference scenario, but it is important to show whether the effects of the alternatives are relatively big or small.

15. Was extra attention spent on local interests and variation?
    - Yes, a lot of municipalities were involved, and we also calculated with local models to show the impact of the project on their region.

16. In the views sent in as a response to the Structure Vision, I found people from Waardenburg that would have liked to see a valuation of air and sound pollution in DALY's. This is not common; has it ever been done, or should it be done?
    - We used the standard methodology, so this was not included. If it was included, I am not sure if we would have had enough input for this. DALY's are difficult to measure anyway.

17. For transparency it was good to at least include the EIA results in the CBA. Is this a standard practice?
    - First monetised, if not then quantitative or last qualitative. In that order.

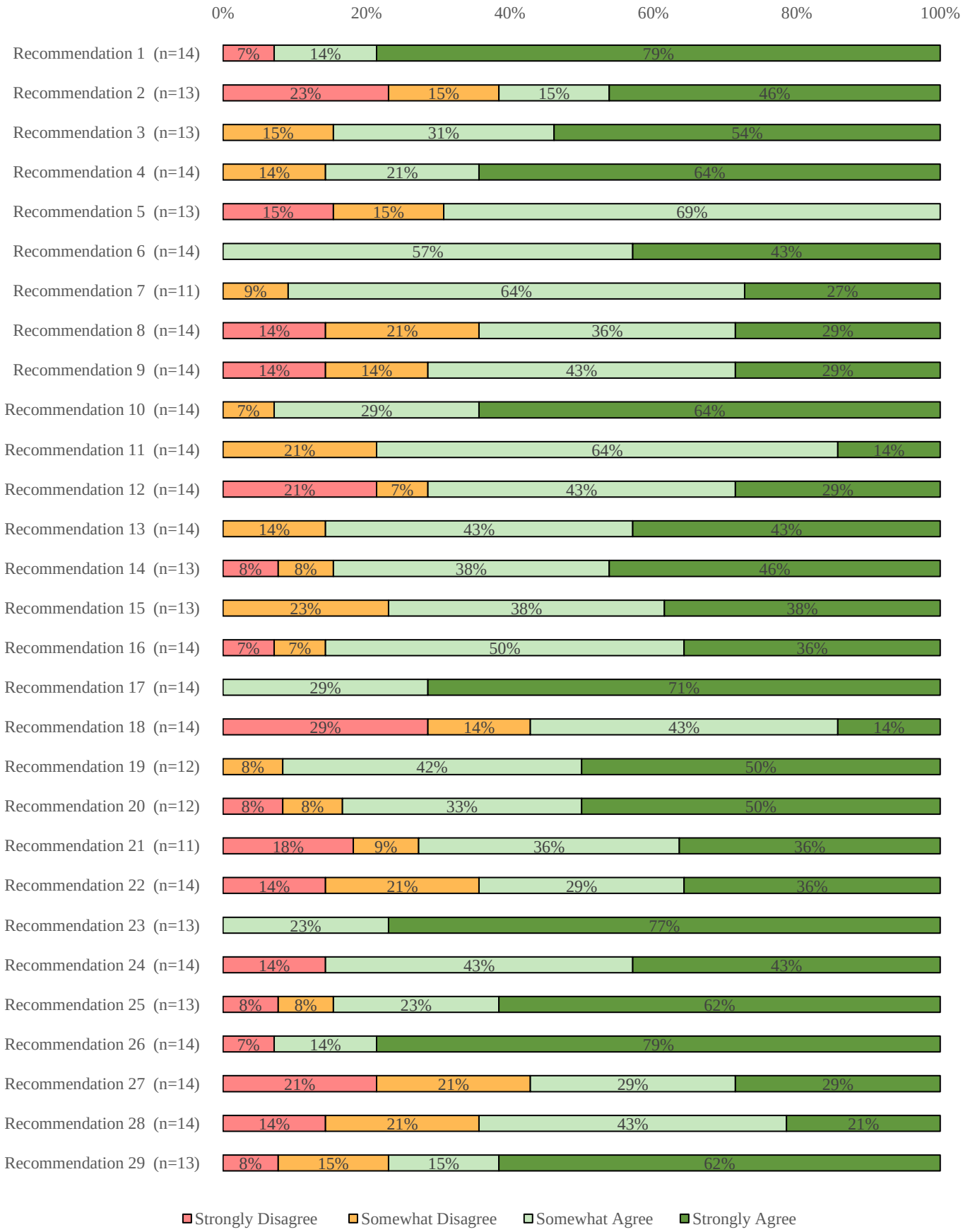
18. Did you present the CBA separately to other interested parties than just governmental bodies?
    - I do not think it was published and explained separately. We did have discussions with the client to discuss the outcomes and quality of the report. It could have been discussed during the information evening. Everybody could see it there, but we didn't actively go present it.

19. Do you understand that the CBA can be a Blackbox to citizens?
    - Everyone who does not understand it will see it as a Blackbox. If you understand the material, then it is completely transparent. This also goes for models, people experience it as a Blackbox, but the models are explained very well, you just need to read the stack of paperwork associated with it.
    - In the end, it comes down to trust, and the moment they start talking about a Blackbox it indicates a lack of trust. In my opinion, the CBA is not a Blackbox.

20. Would be a good idea to include a standard list of effects that have to be mentioned in each CBA, so that you do not have to worry whether something is missing because it was deliberately left out or forgotten or that no effects are estimated.
    - Beforehand an assessment framework is made, it is not standard, but generally, the same things are included. People can't grasp what congestion means because to them it's a long line of vehicles outside their door and to us, it's just numbers. The technical aspect versus the real-life expectations differs a lot.
    - You can simplify it as much as possible, but trust is key. If you involve people back-to-back in the project and keep involving them then you create trust. We of course give people feedback on what happened with their suggestions, but that is not on a CBA level, that happens much earlier in the process. A lot of the 300 suggestions we got were not relevant to the project, but local issues that the municipality should deal with.

11.7 Feasibility & Level of agreement per suggested improvement

Suggested improvement	Level of Agreement	Feasibility (multiple choice)	Average feasibility (1-10)	Certainty (1-10)
27	54%	38%	4.6	8.5
22	62%	38%	5.0	7.7
29	75%	46%	6.1	7.1
4	85%	54%	6.9	6.9
12	69%	38%	5.4	6.9
28	62%	31%	4.6	6.9
9	69%	31%	5.0	6.2
10	92%	54%	7.3	6.2
21	70%	30%	5.0	6.0
5	67%	25%	4.6	5.8
3	83%	42%	6.3	5.8
26	92%	50%	7.1	5.8
25	83%	38%	6.1	5.5
8	62%	15%	3.8	5.4
23	100%	54%	7.7	5.4
2	58%	8%	3.3	5.0
15	75%	25%	5.0	5.0
18	54%	0%	2.7	4.6
19	91%	36%	6.4	4.5
20	82%	27%	5.5	4.5
7	90%	30%	6.0	4.0
1	92%	31%	6.2	3.8
6	100%	38%	6.9	3.8
11	77%	15%	4.6	3.8
13	85%	23%	5.4	3.8
17	100%	38%	6.9	3.8
14	83%	17%	5.0	3.3
16	85%	15%	5.0	3.1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