Uncertainties in the decision-making process of megaprojects : the Zeebrugge New Sea Lock

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Abstract

Complexity and uncertainty are inherent to megaprojects. While the social cost-benefit analysis (SCBA) and environmental impact assessment (EIA) are increasingly used to support decision-making in megaprojects, these instruments often ignore and avoid uncertainty communication, documentation and analysis. By using a conceptual uncertainty matrix for decision-support analyses, this paper questions how uncertainties are taken into account in the SCBA and EIA when making decisions. A document analysis is applied to the SCBA, EIA and other project documents from the research (planning) phase of an ongoing sea port megaproject in Zeebrugge, Flanders. The results show that uncertainties are barely documented nor analyzed in the SCBA and EIA, but arise later during the decision-making process; mainly about which plan alternative is the best for achieving the project's objectives. Uncertainty or ambiguity about 'the best alternative' results from stakeholders' different interpretations of the SCBA and EIA. The paper reveals that research about megaproject uncertainty and decision-making should not be limited to the boundaries of either an SCBA or EIA. We need to further enlarge our research scope, and look at the dynamic interplay between uncertainties; multiple decision-support instruments; stakeholders' different interpretations of these instruments and perceptions about uncertainties; decision-making; and the general process.

Keywords: Infrastructure planning; Ports; docks and harbours; Project Management

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1. Introduction

Complexity and uncertainty are related and inherent elements of the planning, design and decision-making process of megaprojects. They pose planners and decision makers with the difficult challenge of planning for an uncertain future, especially for megaprojects, which are more complex and involve many uncertainties due to their large-scale character, their high investment cost, the many affected and involved stakeholders, and their long time horizon (Flyvbjerg, 2014). The social cost-benefit analysis (SCBA) and the environmental impact assessment (EIA) are two important instruments that support decision-making in megaprojects. The SCBA is a socioeconomic assessment tool to compare alternatives based on direct, indirect and external effects. It takes into account the possible impacts from a broad welfare perspective (van Wee and Rietveld, 2013), including societal effects such as pollution, environment, safety, travel times, health, etc. The SCBA's aim is to monetize every effect, allowing for an easy to understand comparison of the costs and benefits of different alternatives. (Brent, 2006). The EIA assesses the consequences of one or multiple alternatives or policy actions on the natural, spatial and social environment (Wathern, 2013). Both instruments fit the perspective of the dominant rational planning model of 'predict and control', making informed decisions based on future forecasts and predictions (Beukers et al., 2012, Terryn et al., 2016, Giezen et al., 2015, Nicolaisen, 2012). Both SCBA and EIA have become widely used instruments in the appraisal and evaluation of large infrastructure projects in Flanders and many other countries (Bristow and Nellthorp, 2000, Haezendonck, 2008, Mackie, 2010).

However, the aim of SCBAs and EIAs to provide hard scientific evidence about forecasts and predictions – supporting the idea that decisions can be made in a rational way – is problematic for two reasons. First, it has long been known that decision-making and planning is irrational (Banfield, 1959). Decision makers are limited by time, budget and knowledge constraints, called bounded rationality (Simon, 1997). Decision-making is chaotic, coincidental (Cohen et al., 1972), and subject to windows of opportunity (Kingdon, 2003). It is a trade-off between the heterogeneous objectives, opinions, preferences and perceptions of involved and impacted stakeholders (Gil, 2017, Macharis and Nijkamp, 2013). Costs are often underestimated and benefits overestimated (Flyvbjerg et al., 2009). Second, there are limitations to the SCBA and EIA itself. In practice, uncertainties are barely communicated and receive few attention in SCBAs and EIAs (Nicolaisen, 2012, Leung et al., 2016). SCBAs and EIAs are static and create the illusion that we can exactly predict the future (Beukers et al., 2012). The problem then becomes that, if we base our decision on SCBA/EIA results, the alternative chosen can be influenced by dynamic uncertainties or unforeseen changes that were not accounted for in the SCBA/EIA. This impedes the value and potential use of these instruments. Nevertheless, despite uncertainties, it is still better to base decisions on (S)CBA results than on a random selection (Asplund and Eliasson, 2016).

We question in this paper '*how are uncertainties taken into account in the SCBA and EIA of megaprojects when making decisions?'*. Through a document analysis of a single case study in Flanders – an ongoing port project – we aim to illustrate (I) to what extent the uncertainties communicated – or not – in the SCBA and EIA align with the uncertainties that arise afterwards during the decision-making process, and (II) how the uncertainties in the SCBA and EIA impact decision-making, and how decision-making in turn impacts uncertainties.

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Current research on megaproject decision-making and their supporting analyses are limited to research on either the SCBA or EIA, resulting in two different streams of literature, with a dominant focus on CBA research in megaproject literature. Annema (2013), Annema et al. (2017), and Eliasson and Lundberg (2012) illustrate to what extent the (S)CBA influences decision-making in megaprojects or transport infrastructure. Highly cited Authors like Flyvbjerg (2004, Flyvbjerg, 2017), Cantarelli (2010) and Skamaris (1997) have extensively discussed megaproject problems like cost overruns and poor results, due to inaccuracies in cost and benefit estimates, often through large quantitative data sets on transport infrastructure projects. Nicolaisen (2012), Mouter et al. (2015), Welde and Odeck (2011) discuss that uncertainties need to be better managed, communicated and addressed more prominently in (S)CBAs. Similar, Bond (2015), Cardenas and Halman (2016) offer methods for better managing and coping with uncertainties in (E)IAs, while Leung et al. (2015) stress that practitioners need more guidance on how to communicate uncertainties in EIAs.

Despite their relevance, these papers narrow their focus to the boundaries of either an SCBA or EIA. Decisions however are based on the weightings of multiple criteria (Macharis and Nijkamp, 2013), not limited to only socioeconomic (SCBA) or environmental (EIA) concerns. Furthermore, narrowing down the research scope to one instrument, as well as using large quantitative data, ignores depth of decision-making processes and its specific steps in which both instruments are embedded and have influence. The decision-making process of megaprojects itself is characterized by complexity and uncertainty (Priemus et al., 2013, Bertolini and Salet, 2008, Salet et al., 2013). New to existing literature is that this paper (I) researches how uncertainties are documented in both the SCBA and EIA, and (b) analyzes the impact of both instruments on the decision-making process and how both instruments are used differently by stakeholders.

Section 2 explains the concept ‘uncertainty’, followed by the document analysis methodology in section 3. Then, the case is presented in section 4, followed by the results in section 5, and a discussion and conclusion in Sections 6 and 7.

2. The concept ‘uncertainty’

We adopt the uncertainty framework by Walker et al. (2003), later enriched by Kwakkel et al. (2010). The framework – an uncertainty matrix – is intended to enhance the communication of uncertainties within model-based decision support analyses among policy analysts, policy makers and stakeholders (Kwakkel et al., 2010, Walker et al., 2003). Table 1 shows a simplified uncertainty matrix for the purposes of this paper. The framework defines uncertainties by three dimensions.

The level dimension focuses on the degree of uncertainty, from determinism – we know everything precisely – to total ignorance – we do not know what we do not know (Walker et al., 2003). In between are four uncertainty types: *shallow uncertainty*, where the likelihood of uncertain scenarios can be calculated; *medium uncertainty*, where scenarios can be ranked but without specifying the likelihood; *deep uncertainty*, where scenarios can be recognized but not ranked, thus considered equally likely scenarios; and *recognized ignorance*, where the possibility of being wrong is kept open (Kwakkel et al., 2010, Walker et al., 2003).

The nature dimension defines the nature of uncertainty through three different types: *epistemic uncertainty* due to imperfect knowledge; *variability* is the inherent uncertainty or randomness in input data, parameters… in the model; and *ambiguity* is uncertainty as a

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consequence of different interpretations of data, acknowledging different stakeholders' frame of value, opinions, knowledge, objectives and perceptions (Kwakkel et al., 2010).

The location dimension specifies where in the SCBA and EIA models and analyses the uncertainty occurs: *context*, the conditions, circumstances and stakeholder values that underlie the choice of the system boundary; *model*, either a lack of sufficient understanding of the identified system (context), or the computer model itself (bugs, errors); *input data* uncertainty associated with determining parameter values; the accumulated *model outcome uncertainty* or prediction error caused by uncertainty in *context*, *model*, and *input data*. The '*decision-making process*' is added to the original framework as location to categorize uncertainties that arise outside the boundaries of the SCBA or EIA, but during the process.

3. Research method: document analysis of a single case

The document analysis is focused on a single case study. The megaproject under consideration involves the development of a new and second sea lock in the port of Zeebrugge. "A case study is an empirical method that investigates a phenomenon in depth and within its real-world context" (Yin, 2017). In-depth case-study research is a necessity to understand a complex issue (Flyvbjerg, 2006), and to answer this paper's research question on megaproject decision-making under uncertainty. The Zeebrugge case fits the definition of megaprojects well: an estimated cost of over one billion euro; many involved and affected stakeholders; and a long time horizon. It is a representative case for Flanders, because it follows a similar process and procedure for decision-making as other large Flemish infrastructure projects. The case chosen is an ongoing project, in which the research (planning) phase came to an end in June 2019, marking the start of the project (design) phase. A decision has already been made for a preferred plan (alternative), for which an SCBA and EIA were made to support decision-making and compare plan alternatives.

This paper uses a document analysis as the main research method. Analyzing documents requires the researcher to interpret its content, in order to gain an understanding and develop empirical knowledge (Bowen, 2009). The (a) SCBA and EIA are the main documents in this case study, extended with other project documents: (b) SCBA and EIA guidelines; (c) the 'preferred decision', which captures the decisions made and the arguments for (not) choosing a specific alternative; (d) the summaries of the consultation rounds among public/private institutions, and the public inquiry; (e) informational documents about the project, and (f) press articles. All these documents date from 2016 to June 2019. They are free to consult through the project's website, and are listed and explained in Appendix 1.

The document analysis method was chosen as it provides a structured methodology to answer the research question in different steps through a combination of a content, discourse and narrative analysis (Hijmans, 1996). A *content analysis* looks at what is actually written in the documents, while a *discourse analysis* looks at the way a message is presented, the wording of argument patterns. Table 2 provides an overview of which document is used for which part of the document analysis, with reference to their number in Appendix 1. Step one looks at uncertainty documentation requirements in the SCBA and EIA guidelines (b), how they are translated in the project's SCBA and EIA (a), and lists the specific documented uncertainties. Step two illustrates how the SCBA and EIA influenced decision-making, by looking at the arguments in the 'preferred decision' (c), and the summaries of the consultation rounds and public inquiry (d). We look specifically at how the questions or uncertainties raised in (d) has influenced the argument patterns and motivations in the follow-up versions of (c). In step

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three, we interpret and discuss the results from step one and two. The informational documents (e) and press articles (f) are subject of a *narrative analysis* to tell the case's story.

4. Megaproject case: New lock in the Port of Zeebrugge

The port of Zeebrugge is located in Flanders (Belgium), near the North sea, as seen on Figure 2. The town Zeebrugge is located within the boundaries of the port, as seen on Figure 3, inhabiting about 4300 people spread across three neighbourhoods: Zeebrugge-Dorp, Stationswijk and Strandwijk. It is Flanders' second most important port, ranked number one in the world for the shipment of cars, and provides about 10,000 direct and 10,000 indirect jobs, with around 400 companies. The port currently has two locks. The Visart-lock, built in 1907, is outdated and non-operational. The second lock, the Vandamme-lock, was built in 1984 to allow the port to extent its activities. Today this lock has to be operational full-time. Signs of decay and recurrent malfunctioning made the Zeebrugge port and the Flemish Government agree on the need for a new second lock. Between 2004 and 2016, a lot of research was conducted to find a solution, but this never led to any significant progress.

The project was given a kick-start halfway through 2016, when the Flemish Government signed the 'starting decision', meaning the project would follow the procedures and process of the new (2014) 'decree for complex projects'. This decree offers projects the possibility to follow a sequential procedure of four steps – the exploration phase, the research or planning phase, the design or project phase, and the implementation phase. The project was renamed *Improving nautical accessibility to the (rear) port of Zeebrugge*, which also became the project's main objective, next to several secondary criteria.

The 'starting decision' marked the end of the exploration phase and the beginning of the research phase, in which all possible alternative plans within reason were identified. Alternatives were identified through (I) workshops with the project team, (port) companies and inhabitants; and (II) a public inquiry. Alternative plans could be suggested by anyone, of which the project team would decide whether or not these suggestions were reasonable. There was an agreement that each alternative plan should not only contain a new lock, but also a new mobility plan to separate local neighborhood traffic and port traffic, including new roads for cars, public transport and bikes or pedestrians. The new lock would be accompanied by a new regional road for port and ongoing traffic – called the NX. Six overall alternatives were identified, officially published in the *alternatives research note* (May 2017), and researched until December 2017. The location of the alternatives can be seen on Figure 5.

The three alternatives in the west all required the removal of the old Visart lock. In Alternatives one to five, one new lock will be built, and the current 'Vandamme lock' will be renovated in 2049-2050, seizing its operations for two years. Alternative 6 – 'Verbindingsdok' – considers the construction of two new locks deeper into the rear port, requiring the removal of the current 'Vandamme lock'. Four of these alternatives hold two sub-alternatives, in which the NX regional road could be planned above ground, or as a tunnel.

The research resulted in three main reports, an SCBA, an EIA and a nautical screening (NS). In March 2018, A preliminary draft – officially called *predesign for the preferred decision* – was published, in which Alternative 2, *Visart-lock current location with NX as tunnel (1)* was chosen as 'best alternative'. The motivation at that point was limited to providing arguments for eliminating the other alternatives and ending up with Alternative 2, rather than explaining

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why this is the 'best alternative', It was merely stated that Alternative 2 meets the project's primary objective, based on the results from the SCBA, EIA and NS.

During the two months that followed, consultation rounds were held among the involved organizations (e.g. Port of Zeebrugge, City of Bruges, Flemish Department of Environment…) to collect concerns, suggestions and advice on the *predesign preferred decision* and the motivation given. Despite critiques from several actors, Alternative 2 remained the preferred alternative, as expressed in the *design preferred decision* (December 2018) – an adjustment of the *predesign preference decision*. Again, critical and concerned voices – mainly by inhabitants supported by some political parties – pointed at the impact Alternative 2 would have on Zeebrugge town. One of the main concerns was that it would create a barrier between the neighborhoods *stationswijk* and *Zeebrugge-Dorp*, of which the latter would get squeezed in between two operational locks. According to the concerns, this could have a major impact on the future and livability of Zeebrugge. For this reason, Alternative 6 was favored by several stakeholders, of which the City of Bruges and inhabitants of Zeebrugge are frontrunners. This was strongly represented in the 'notices of objection' that were submitted during the 60-day period public inquiry (January-March 2019).

After the consultation rounds and the public inquiry, the motivation for the chosen alternative and the rejected alternatives was adjusted and lengthened, as the list of actions to be undertaken during the design/project phase to deal with questions and concerns was extended. This resulted in the *principal determination preferred decision* on May 10th, 2019, with an official approval for the chosen alternative by the Flemish Government. After the advice of the Council of State, the final *preferred decision* was released on June 28th, 2019. The *final preferred decision* is an official and regulative decision, which contains the determination of the chosen alternative at the strategic level of the complex project. Possible legal consequences might be linked to the decision. It is a 'no point of return', and marks the start of the design/project phase, during which alternative designs and projects are identified and researched, traversing a similar procedure of decision-making as during the research phase. Table 3 summarizes the project's important moments.

5. Document analysis. Uncertainties and decision-making in the Zeebrugge New Sea Lock Megaproject

Uncertainties in the SCBA and EIA: not described in detail, nor analyzed

Three types of risks that can influence the deviation around the mean values of costs and benefits are identified in the SCBA guidelines: policy uncertainty, technical risks (uncertainties about the model variables), and market risks. The guidelines state that the SCBA should provide insights on the impact of uncertainties on the outcome of cost and benefit calculations. Sensitivity analysis for technical risks and scenario analysis for policy uncertainty and market risks are put forward as methods to provide insights on these uncertainties. In both methods changes are made to the values of the input data or parameters, to determine for which estimated variables the project is most sensitive.

In the Zeebrugge project's SCBA, only one uncertainty is identified: the total costs. A sensitivity analysis is conducted, by increasing and decreasing the total costs of each alternative by 25%. Since this is an increase/decrease on the total estimated costs, the sensitivity analysis does not provide detailed information about the sources of uncertainty,

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the difference in uncertainty for different cost items, and does not show which variable affects the SCBA outcome the most. In both scenarios, the benefits of all alternatives still surpass the costs. Within the uncertainty framework, this can be described as a variability uncertainty (nature) in the model input data and model outcome (location) because it can be interpreted as a general prediction error. Since the SCBA did not determine the likelihood of each scenario, the scenarios are considered equally likely.

The EIA guidelines acknowledge that uncertainties are unavoidable, but indicate that they can lead to unreliability of the results, which in turn harms the value for using an EIA in decision-making. Tips are provided on how to deal with uncertainties: work with different future scenarios; make uncertainties explicit as much as possible; use adaptive strategies with mitigating measures and monitoring; and eliminate known uncertainties as much as possible. Uncertainties in the EIA report must be documented under a specific chapter entitled 'knowledge gaps'.

In the Zeebrugge project's EIA, this chapter is limited to one knowledge gap about the eco-hydrological effects of Alternative 6 Verbindingsdok on a neighboring natural environment categorized as 'Special Protection Zone'. Eco-hydrological effects are expected, but because of this knowledge gap, it cannot be concluded that there is no chance of a significant negative impact. These effects were merely based on expert judgement, and no groundwater modelling was conducted. This knowledge gap was not further researched, and must therefore be interpreted as an epistemic uncertainty (nature), due to a lack of knowledge. As for the level of uncertainty, this is a recognized uncertainty, since no future scenarios about the effects were identified. The uncertainty's location is the context, since it was excluded from further modeling, thus left out of the boundaries of the researched system or context.

Uncertainties arising during the decision-making process

While uncertainties are barely mentioned nor researched in the SCBA and EIA, the knowledge gap mentioned in the EIA was still an important part of the first draft of the report '*preferred decision – predesign preferred decision*'. As mentioned earlier, no real arguments were given for choosing Alternative 2. It was said to be a relatively fast solution, which suits the objective of realizing a second new lock as soon as possible. When reading through the arguments of eliminating other alternatives, Alternative 6 was not chosen for two reasons. Its cost price was regarded too high, since it required the construction of two new locks. In absolute numbers, this is true. If also the benefits are considered however, it was ranked second best above Alternative 2 in the SCBA. The most extensive argument was related to the knowledge gap. If it would turn out that Alternative 6 has a negative impact on the surrounding protected natural environment, this alternative cannot be permitted due to environmental legislation. Since this remained an unsolved knowledge gap or epistemic uncertainty, no risks were taken and Alternative 6 was eliminated. The argumentation for eliminating

Alternative 6 fits the discourse of risk-averse behavior. Instead of dealing with risks and uncertainties, decision makers prefer to ignore and avoid risks (Bruzelius et al., 2002). Risk avoidance in this case is facilitated by environmental legislation, which states that if there is any uncertainty about possible negative effects on nature categorized as 'special protection zone', this alternative cannot be permitted or licensed, and thus risk is pushed out.

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After it was known from the predesign preferred decision that Alternative 2 would be pursued, many concerns and questions were raised. These concerns are well-documented and answered to by the project team in the summaries of the consultancy rounds and the public inquiry. First, most concerns were raised about the potential impact of the project on the direct environment, mainly the neighborhoods Stationswijk and Zeebrugge-Dorp. Since the project definition of 2016, one of the conditions was that the project would facilitate the local relations between the different neighborhoods as much as possible. Dissatisfied inhabitants as well as several public actors such as the City of Bruges pointed at the environmental impact (noise, emissions, pollution, traffic, etc) during the construction and operational phase; the impact on livability; and the uncertain perimeter of expropriations which will be determined during the project phase. It was known from the EIA that Alternative 2 would have a significant negative impact on the environment, livability and spatial cohesion of Zeebrugge. However, the exact spatial impact remains an uncertainty. Despite not being identified as an uncertainty in the EIA, these concerns can thus be interpreted as spatial impact uncertainty, since the impact on livability cannot be simply expressed in a single number. This is a recognized and epistemic uncertainty, located within the decision-making process since it was not identified as an uncertainty within the EIA boundaries.

Second, critique was given both during the consultation rounds as during the public inquiry towards the fact that the 'knowledge gap' in Alternative 6 was not further researched, despite being used as an argument for elimination of this alternative. It was no secret that the Verbindingsdok Alternative was favored by several actors, such as most inhabitants of Zeebrugge, and the City of Bruges. They pointed at the benefits of the Verbindingsdok Alternative coming forth from the research reports. The biggest argument was that this alternative would spare the town because of its location deeper in the rear port. The project team responded to these comments in the following drafts of the preferred decision by lengthening the arguments for (not) choosing a specific alternative, as well as increasing the list of actions to be undertaken during the project and implementation phase in order to deal with the questions and concerns. Alternative 2 remained the chosen plan in the following drafts and the final preferred decision.

From the document analysis, it becomes clear that there is a discourse of uncertainty-avoidance with the decision maker and project team. There is no identification process of uncertainties prior to the SCBA and EIA, and both instruments document uncertainties to a bare minimum. The only uncertainty documented in the EIA nevertheless impacted decision-making, since it provided the main argument for eliminating Alternative 6. Vice versa, decision-making impacted uncertainties, in the sense that the choice for Alternative 2 initiated discussions and concerns about the spatial impact of a New Lock in between two town neighborhoods, which remains an uncertainty. This illustrates a non-alignment between uncertainties in the SCBA/EIA and decision-making process in this case, and shows that not properly identifying uncertainties in decision-support instruments does not eliminate uncertainties. In the following section, using the uncertainty framework from Kwakkel et al. (2010), we further discuss how stakeholders use the SCBA and EIA differently during the process, and the implications of this paper's results in light of other research.

6. The ambiguity and complexity of uncertainties in megaprojects

The decision-making process following the case's SCBA, EIA and *predesign preferred decision* can be interpreted as what Kwakkel et al. (2010) call ambiguity as the nature of uncertainty. Ambiguity is uncertainty that comes forth from different perceptions or frames

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of value about what the 'best alternative' is. The results and data from research reports can be interpreted in different ways, depending on different perceptions, objectives and preferences of different stakeholders. In this case study, the City of Bruges and the inhabitants are most concerned about the livability of the town Zeebrugge, so they don't care much for numbers on, for example, the cost of the project. They prefer Alternative 6 for its more remote location, which in their opinion contributes more to strengthening the locations between the neighborhoods and revitalizing the town. Therefore, they rely more on results from the EIA, in which spatial impact in terms of noise, air quality, spatial cohesion and relations, is negative for Alternative 2, but positive for Alternative 6. For this reason, a lot of questions were raised about the lack of research on the knowledge gap in Alternative 6.

Vice versa, the Flemish Government, who eventually decides on the alternative plan, prefers Alternative 2, mostly because its cost price and construction time are more reasonable than with Alternative 6, for which it draws its argumentation in the *final preferred decision* from the SCBA results. It is obvious that the Flemish Government is more concerned with the cost, because they pay for the investment. Based on the nautical screening, each alternative meets the project's main objective, improving access to the rear port. Choosing a 'best alternative' then becomes the result of an interpretation of the results of the SCBA and the EIA for secondary criteria, depending on individual perceptions, objectives and preferences of different stakeholders. Therefore, the 'best alternative' is an ambiguous uncertainty. Table 4 places all uncertainties from the document analysis in the empty framework from Table 2.

In the Zeebrugge case, 'the best alternative' as an ambuguity and uncertainty dominates discussions between stakeholders. Opposite of this reality, dominant megaproject literature focusses more on the inaccuracy of traffic forecasts and assumptions about the monetary costs and benefits (e.g. Flyvbjerg et al., 2005, Nicolaisen, 2012). Cost overruns (cost), time slippages (timing) and poor project results (quality) following inaccuracies in CBA modelling are the key indicators of a project's success or failure in dominant megaproject literature. Forecasts should be regarded as uncertain. On the one hand, the Zeebrugge case fits the criteria for being at risk of forecasting inaccuracy. The port traffic forecasts for when a second sea lock would be built present themselves as an exact calculation of what the far future will look like, only considering one growth scenario. Even more striking, the assumptions are not based on forecasts of international sea freight traffic and port competition, but on the assumption that the promise of additional infrastructure will secure future growth. These forecasts are of crucial importance in the weighing of alternatives. They not only determine the effects (costs and benefits), but also the crucial point in time at which a second sea lock needs to be operational. Inaccuracies in this forecast also mean inaccuracies in the cost and benefit estimates.

At this point in time it is too early to evaluate the Zeebrugge case on forecasting inaccuracy. However, given the poor track record of transport infrastructure megaprojects on forecasting accuracy, the project team should be aware of this, while there is still the possibility in the design (project) phase to think about flexible strategies for dealing with unforeseen scenarios. On the other hand, there is a clear difference between what dominant megaproject literature regards as important to the project's success, and what is perceived as most important by the stakeholders in the case of Zeebrugge. In this case study, there is more discussion – ambiguity – about the 'best alternative', related mostly to the uncertainty about the town's future – the spatial and environmental impact – given the choice for Alternative 2. No model can predict what the future of the town will look like during the construction and operation of a new Visart Lock right between two neighborhoods, nor how this large infrastructure

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investment will impact the livability, social cohesion, or spatial and environmental quality of Zeebrugge. These are complex uncertainties, and very difficult to grasp within the boundaries of an SCBA and mostly an EIA.

Following this reasoning, the document analysis has shown that uncertainties in megaprojects cannot simply be understood within the boundaries of either an SCBA or EIA. This becomes clear from the fact that specific concerns only boiled up after the first decision was made for Alternative 2, and thus after a decision based on the SCBA and EIA results. In other words, a decision can be based on research reports, but as in this case, once a plan is chosen, the project is steered in a specific direction that triggers additional questions, uncertainties or concerns due to the project's complexity and large number of involved and affected stakeholders. In other words, the SCBA and EIA are mere starting points in which uncertainties could reside, and it is difficult to capture all uncertainties following decisions made later on in the process. Of equal importance after the initial decision are the different interpretations of data and results, for which this paper has illustrated how both instruments are used differently by different stakeholders, which can lead to ambiguity.

Nevertheless, the SCBA and EIA are an important first step in acknowledging and assessing uncertainties perceived by different stakeholders. However, the SCBA and EIA in this case poorly document and acknowledge uncertainties, which can harm credibility and the potential use of these reports (Annema et al., 2017, Leung et al., 2015, Leung et al., 2016). An SCBA and EIA will always be potentially interpreted differently by different stakeholders, but the more uncertainties are absent in these assessments, the further these reports drift from the reality of the complex and uncertain-prone process in which they are embedded. In addition to existing research, this paper has illustrated in detail at the level of a single case study megaproject that the SCBA and EIA cannot be detached from each other, nor from the complexity of the decision-making process, and that uncertainties reside in both these instruments as well as in the process in which they are embedded.

7. Conclusion

Uncertainty and complexity are inherent to the planning, design and decision-making process of megaprojects. We researched how uncertainties in the SCBA and EIA are taken into account when making decisions; and illustrated how they are nearly absent in the Zeebrugge project's SCBA and EIA. Therefore uncertainties did not have a direct impact on the first decision made. This however does not align with the uncertainty based questions and concerns raised afterwards, highlighting the ambiguity of what the 'best alternative' is in this case study. These uncertainty based concerns will have a big impact on the decisions still to be made in the design (project) phase, and are harmful for the credibility and value of the research results from the SCBA and EIA.

The paper shows that: (I) uncertainties are not limited to the boundaries of an SCBA or EIA, and they should not only be researched individually on uncertainties, but both within the broader context of the decision-making process as a whole; (II) these instruments are used differently by stakeholders, which can result in uncertainty or ambiguity about the best alternative; (III) there is a possible difference between what stakeholders perceive as uncertainties, and what mainstream megaproject literature pinpoints as uncertainties. If we want to understand the complexity of megaproject decision-making under uncertainty, we need to try to enlarge our research scope as much as possible, and look at the dynamic interplay between uncertainties, multiple decision-support instruments, decision-making, and the general process.

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Furthermore, practitioners need to understand that limiting communication on uncertainties during the research phase in the SCBA and EIA for whatever reason does not result in an uncertainty-free process. If we want to increase the value as well as the quality of an SCBA or EIA, communication on uncertainties or possible future scenarios needs to be included as early as possible, opening up the debate among stakeholders as early as possible, thus including different perceptions. In this way, ad hoc responses to uncertainties can be turned in a more proactive way of identifying, understanding, and managing the possible impact of uncertainties collaboratively. However, more research is needed on stakeholders' perceptions on uncertainties in megaprojects, not limited to a single instrument but to the decision-making process as a whole.

The document analysis proved to be a good method to answer our research question, for the paper's main focus on a single project's SCBA and EIA. This was done through a combined content, discourse and narrative analysis. The conclusions however open up other research questions requiring possibly other research approaches. A next step would be to research deeper what happens behind the scenes in the build up towards the SCBA and the EIA, the decision-making and the discussions following decisions made. This requires thinking about the so-called rationality of these instruments in light of the irrationality of a decision-making process. This could help gain a better understanding on perceived uncertainties, rather than those marked as important in conventional literature. More comparative and in depth case studies on this subject are needed. This paper attempted to provide a first step to better understand and illustrate the complexity of decision-making under uncertainty in megaprojects, enlarging the research scope to the interaction between both the SCBA and EIA, as well as the project's decision-making process.

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Appendix 1. Sources used for the document analysis of the Zeebrugge Port project.

Original name (Dutch) – *translation English* – publication date – description
Project documents

1. MKBA Zeesluis Zeebrugge – *SCBA Sea Lock Zeebrugge* – April 2019 (latest version) – the social cost benefit analysis of the project
2. Strategische milieubeoordeling verbetering nautische toegankelijkheid tot de (achter)haven van Zeebrugge – *Strategic environmental impact assessment improvement of the nautical accessibility to the rear port of Zeebrugge* – April 2019 (latest version) – the environmental impact assessment of the project
3. Nautische screening – *Nautical screening* – 2016 – research report on the nautical feasibility of the six alternatives, conducted and written at the same time as the SCBA and EIA.
4. Voorontwerp Voorkeursbesluit – *predesign preferred decision* – March-April 2018 – the first draft expressing the preferred decision for alternative 2, accompanied by a motivation for this choice

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5. Ontwerp voorkeursbesluit – *design preferred decision* – December 2018 – the second draft of the preferred decision alternative 2, with adjustments to the motivation and action plan after the consultancy rounds among private/public expert institutions and advisory commissions
6. Principiële vaststelling voorkeursbesluit – *principal determination preferred decision* – May 2019 – the third and final draft of the preferred decision alternative 2, with adjustments to the motivation and action plan after the public inquiry.
7. Voorkeursbesluit – *preferred decision* – June 2019 – the final document stating the preferred decision, after the advice from the Council of State, with a regulatory status, marking the end of the planning (research) phase and start of the project (design) phase.
8. Alternatievenonderzoeksnota – *alternatives research note* – March 2017 – document at the early stages of the research phase, containing an extensive description of the six alternatives to be researched in the SCBA, EIA and Nautical Screening.
9. Antwoordennota naar aanleiding van adviesronde voorontwerp voorkeursbesluit – December 2018 – *answers following the consultancy rounds for the predesign preferred decision* – this document contains an extensive summary of all the questions or comments given for each advisory commission or consulted public/private (exper) instition, with responses from the project team for each question or comment.
10. Antwoordennota naar aanleiding van het openbaar onderzoek van het ontwerp van voorkeursbesluit – *answers following the public inquiry from the design preferred decision* – March-April 2019 – this document contains an extensive summary of alle the questions and comments submitted from individuals – anonymous in this document – during the public inquiry, with responses from the project team for each question or comment.
11. Synthesenota – *synthesis* – April 2019 (latest version) – a summary of the results from the research phase – SCBA, EIA, nautical screening – for all alternatives, as a first step towards the *preferred decision*.
12. Procesnota – *process note* – December 2018 (latest version) – an informative document including (I) general information (objective, actors, timing) about the project and process, (II) an overview of participation moments and the location of available documents, and (III) a description of the communication approach in favor of the process' transparency.

The above listed documents are free to consult and download in PDF-version at the project's website: https://mow.vlaanderen.be/nieuwesluiszeebrugge/

Other documents

13. Richtlijnenboek Milieueffectenrapportage – *Book of Guidelines for Environmental Impact Assessment* – October 2015 – guidelines for making an EIA. These guidelines were written conjointly by the Flemish Department of Environment, Nature and Energy; and 'Technicum', a subdivision of the international consultancy and engineering company 'Tractabel'. The PDF version can be downloaded for free at the Department's website:
    https://www.lne.be/richtlijnenboeken-en-handleidingen

14. Standaardmethodiek voor MKBA van transportinfrastructuurprojecten – *Standard methodology for SCBA of transport infrastructure projects* – December 2013 – These guidelines were written by Rebel Group, an international advisory commission, on behalf of the Flemish Department of Mobility and Public Works.

Press articles

15. Press articles were gathered from various Flemish news sources using a combination of the search terms 'Port Zeebrugge' and 'Sea Lock'. Sources from between May 2017 and June 2019 were found on the following news websites: https://www.vrt.be/vrtnws/nl/; https://www.standaard.be/; https://www.nieuwsblad.be/; https://kw.be/.

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Table 1. Uncertainty framework based on Walker et al. (2003) and Kwakkel et al. (2010)

Location	**Level (uncertainty degree)**				**Nature of uncertainty**		
	Shallow uncertainty	*Medium uncertainty*	*Deep uncertainty*	*Recognized ignorance*	*Ambiguity*	*Epistemology*	*Variability*
Context (system boundary)							
Model							
Input data							
Model outcome							
Decision-making process							

Table 2. Document analysis, steps and documents used

Steps	**Project documents used**
Step 1	a. SCBA Sea Lock Zeebrugge (1) a. EIA Sea Lock Zeebrugge (2) b. Guidelines for environmental impact assessment (13) b. Standard methodology for SCBA transport infrastructure projects (14)
Step 2	c. predesign preferred decision (4) c. design preferred decision (5) c. principal determination preferred decision (6) c. preferred decision (7) d. answers following the consultancy rounds for the predesign preferred decision (9) d. answers following the public inquiry from the design preferred decision (10)
Narrative analysis	Elements drawn from the documents used in step 1 and 2 extended with: e. alternatives research note (8) e. synthesis (11) f. process note (12) f. Press articles (15)

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Table 3. Important moments in the Zeebrugge New Sea Lock Megaproject

Month	Year	Important moments
	2004	Start of research into a new sea lock for Zeebrugge Port, initiated by the Flemish Government
	2009	'Carcoke site' appointed as the best location, cost estimations for the new sea lock are around 400 milion euro
	2014	Confirmation of the choice for the 'Carcoke site'
July	2016	'Starting Decision' made by the Flemish Government ('Decree of Complex Projects'). The project is officially named *Improving nautical accessibility to the (rear) port of Zeebrugge*. – Start of the planning/research phase
March	2017	'Alternatives, research note' – overview of the six alternatives that will be compared on a strategic level
November	2017	Termination of the research and publication of the initial research reports: 'strategic environmental impact assessment (S-MER), 'strategic social cost benefit analysis' (S-MKBA), 'nautical screening'
March-April	2018	'pre-design preferred decision', choice for the alternative 'Visart-lock, current location with NX as tunnel'. Two month consultation round to collect and process advices and opinions on the 'pre-design preferred decision'.
March	2018	Information rounds for the affected residents (14 March) and other interested residents or parties (15 March)
December	2018	Determination and approval of the 'design preferred decision' by the Flemish Government. 'Visart-lock current location with NX as tunnel' remains the preferred alternative.
January-March	2019	Public inquiry (60 days) for consulting project documents/Research reports, and submitting 'notions of objection'; 750 notions of objections submitted at the end of the public inquiry
May	2019	Approval of the S-MER by the MER-administration, principal determination of the 'preferred decision', followed by a 30 day period during which the 'council of state' has to give its advice, which then leads to the final 'preferred decision', confirming the chosen alternative and marking the start of the project phase (no point of return).
June	2019	*Final Preferred Decision*, confirmed by the Flemish Government, with 'Visart-lock current location with NX as tunnel' as chosen alternative, marking the official start of the design (project) phase
October	2019	Publication of the *Final Preferred Decision* in the Belgian Official Journal, starting a period of 60 day in which it is possible to lodge an appeal against the decision with the Council of State.

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Table 4 Uncertainties in the Zeebrugge megaproject's SCBA, EIA and decision-making process (DM)

Location	**Level (uncertainty degree)**				**Nature of uncertainty**		
	Shallow uncertainty	Medium uncertainty	*Deep uncertainty*	*Recognized ignorance*	*Ambiguity*	*Epistemology*	*Variability*
Context (system boundary)				'Knowledge gap (EIA)		'Knowledge gap' (EIA)	
Model							
Input data			Total project costs (SCBA)				Total project costs (SCBA)
Model outcome			Total project costs (SCBA)				Total project costs (SCBA)
Decision-making process				Spatial impact Alternative 2	The 'Best Alternative'	Spatial impact Alternative 2	

Figure captions

Figure 1. Zeebrugge, Aerial view (Source: https://portofzeebrugge.be/en)

Figure 2. Geographical location port

Figure 3. Port and town of Zeebrugge

Figure 4. Research phase, overview

Figure 5. plan alternatives

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Fig1_Zeebrugge, aerial view

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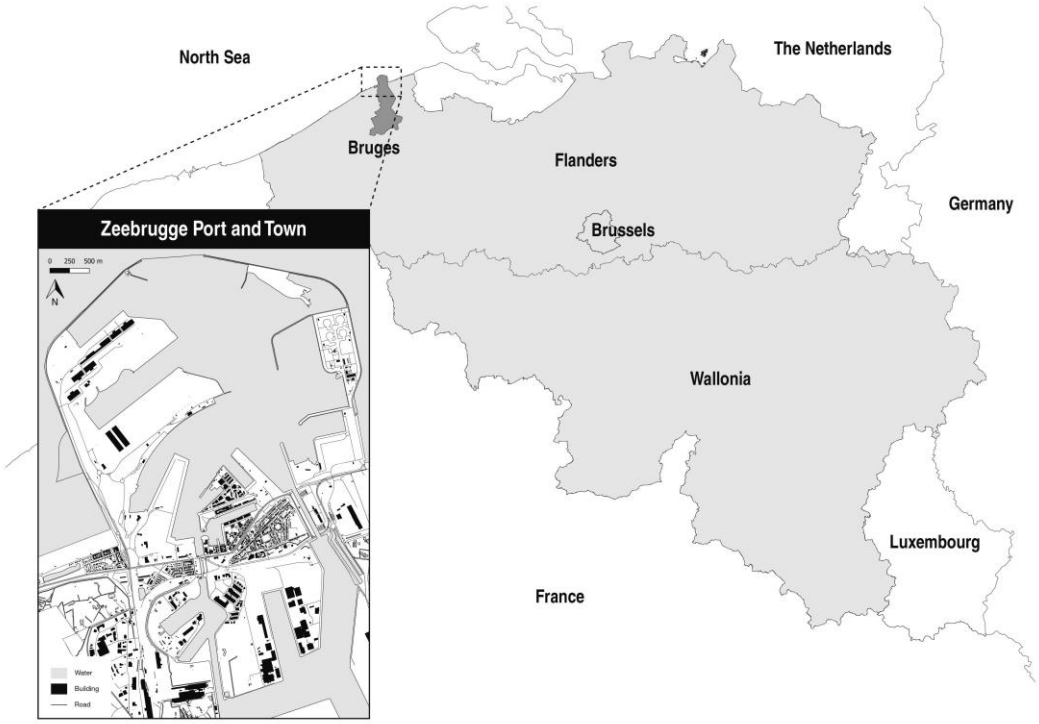

Fig2_Geographical location Zeebrugge

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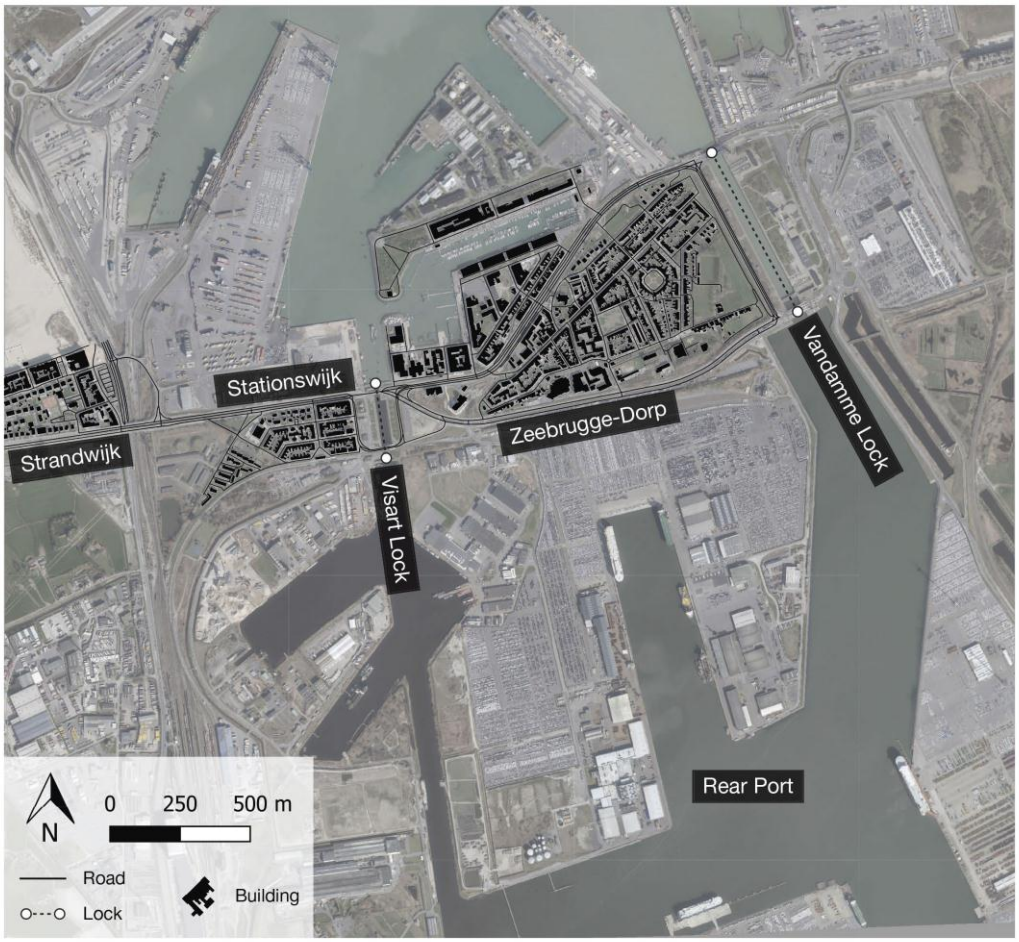

Fig3_Zeebrugge, port and town

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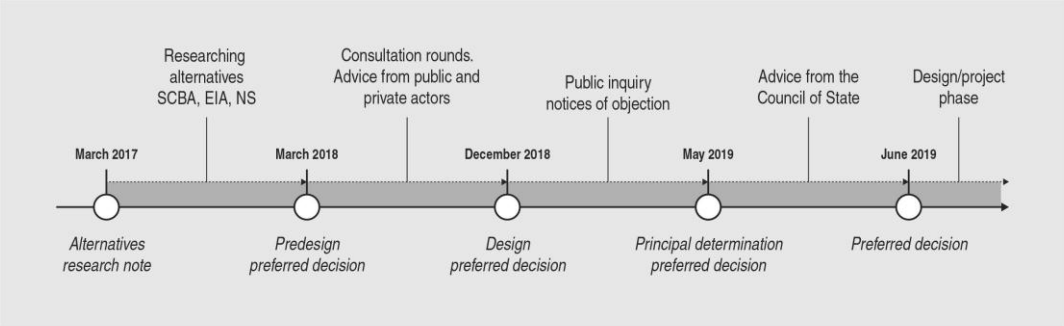

Fig4_Zeebrugge megaproject, research phase

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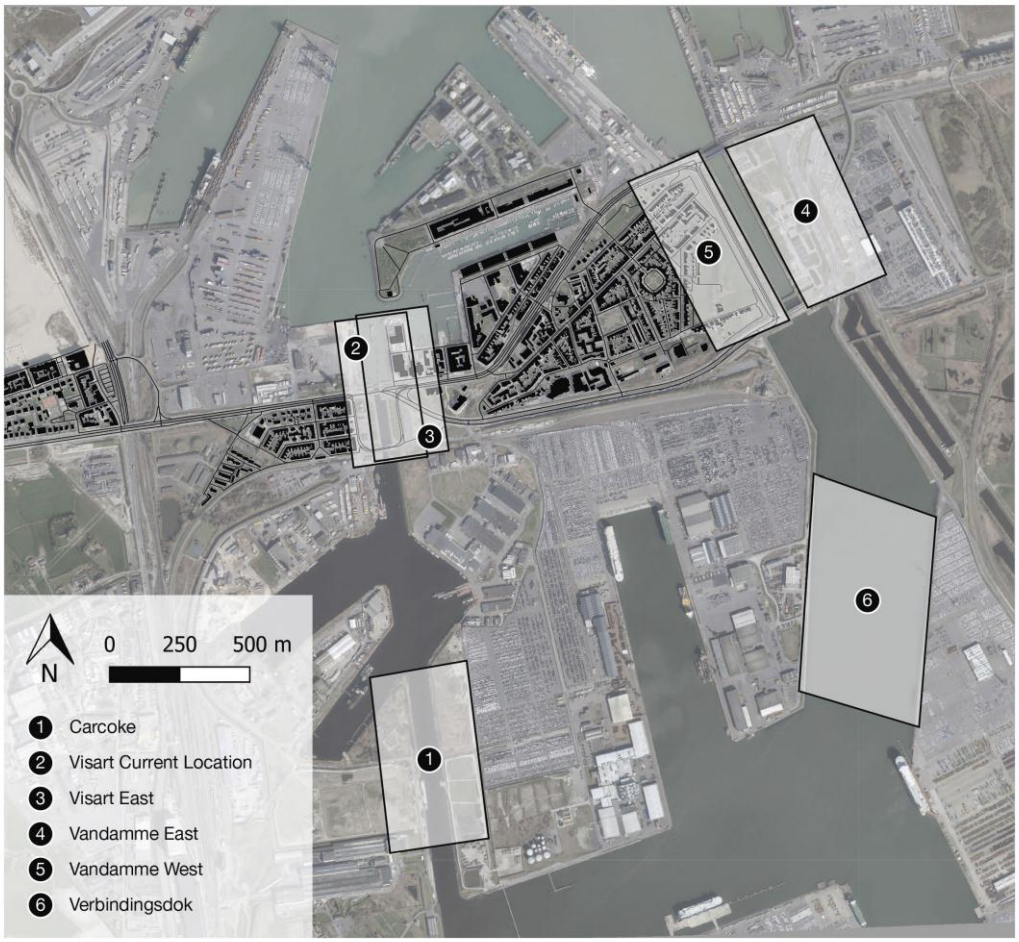

Fig5_Zeebrugge project, plan alternatives