Cost Benefit Analysis for safety projects at sea – Does the method give the entire picture?

Experience from analysis of the Stad sea tunnel

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Abstract

The method used for CBA of safety projects at sea should be altered to include direct and indirect costs related to precautions taken to avoid risk. This is one of the conclusions from a cost benefit analysis regarding a ship tunnel at Stad, carried out in 2007. Stad is a peninsula located on the western coast of Norway. A tunnel here would give seafarers the opportunity to pass by Stad regardless of the weather conditions and ship size. The waters surrounding Stad are difficult, and this stretch of sea is one of the most feared along the entire Norwegian coast. Interviews and two open meetings gave information about how the people and companies react to the current sailing conditions. Information gathered indicates that aspects of great importance to some of the stakeholders, are not captured by the prevailing CBA method. Today, the seafarers take precautions which would not be necessary if a tunnel was built. This represents costs today and savings should the tunnel be built, and thus the savings should be included in the assessment of the tunnel. Research should be carried out to go more thoroughly into the effects, and the method to assess safety projects at sea. New assessments for sea projects should be altered to take these effects into account.

1 Introduction

This paper is based on findings from a Cost Benefit Analysis (CBA) completed for a ship tunnel. The project "CBA for Stad ship tunnel" (Tørset et al., 2007) was financed by the Norwegian Coastal Administration (NCA), and was carried out by SINTEF during 2007. Interviews and open meetings revealed that precautions and adaptations which the seafarers take to avoid dangerous situations at sea, are not sufficiently reflected in the prevailing CBA method, neither in a national nor an international context.

The CBA method developed for Norwegian sea projects (Kystverket, 2007a) is based on national guidelines, not very different from the method used for land transport projects (Statens vegvesen, 2006). The national guidelines correspond to the proposed European guidelines developed in the HEATCO project regarding which effects to include in a CBA (HEATCO, 2006).

The CBA for Stad ship tunnel included interviews and public meetings with seafarers and other stakeholders. The participants described what actions they take today in order to avoid dangerous situations, and gave an assessment of how the tunnel might change the need for such precautions. These actions are related to a general fear level among the sea farers and the local residents living along the coastline. Stad is known among all seafarers along the Norwegian coast for its dangerous waters. The seafarers and others around them take precautions now which would be unnecessary if a tunnel existed. These precautions are either not reflected at all in the CBA, or are reflected only partly through other factors, such as waiting time. These impacts are thus "new" in the sense that they are not included in the current method.

The impacts in question have costs in terms of welfare loss related to them. In a future situation with a tunnel, these costs would be reduced or non-existing, and the savings should be reflected in the method used to assess the benefit of a tunnel.

1.1 The CBA method used

In order to reveal why the current method used does not include the impacts in question, we need to look at what factors are included in a CBA and how they are assessed. We have chosen to focus on two elements; *saved time* and *changes in accident risk*, as the effects which we identified as missing from the current CBA method, were linked to or not yet fully included in the assessment of these two quantitative factors.

The NCA is responsible for impact assessments of sea infrastructure projects, and has provided a manual for carrying out CBAs for projects aiming at improving sailing conditions for ships (Kystverket, 2007a). The method is based on guidelines from the Ministry of finance (Finansdepartementet, 2005). The main quantitative factors in this CBA method includes accident risks and time savings in roughly the same manner as described in the proposed guidelines developed in the EU FP6 Heatco project (HEATCO, 2006).

The analysis of **changes in Accident risk** in the Stad analysis was based on registered fatal accidents and accidents with personal injury reported to the National Insurance Administration. It was assumed that accidents that arose from rolling would be reduced if a tunnel was built, and the statistics of injuries were studied in order to extract the potential reduction caused by the tunnel.

The assessment of the accidents in the Stad analysis included fatalities, personal injuries, material damage of vessels, damage to or loss of cargo, costs connected to salvage, retrieval and/or draining of vessels and costs connected to vessels being out of operation after an accident. The consequences of fatalities and personal injuries were treated more or less the same way.

The unit costs provided by the current CBA method include both costs in real terms and welfare loss. While real term costs consist of measurable costs, the welfare loss consists of reduced life quality and loss of health, including practical and psychic disadvantage for relatives. The description of the current method is ambiguous as to whether the unit costs include anxiety and fear following an accident. It is however clear that the cost factors do not include consequences of near accidents or dangerous situations which do not result in injuries or damage. Furthermore, the influence that the sea conditions outside Stad have on the local community living alongside the coastline are also not included in the current unit costs.

Time savings related to the Stad tunnel were estimated through the following steps:

- Finding the current sailing patterns around the Stad peninsula through traffic registrations (passenger statistics, data from the Automatic Identification System and GPS tracking of the smack fleet)
- Carrying out demand analysis for the opening year and considering induced travel activity caused by the tunnel
- Estimating waiting time in the current situation due to weather conditions
- Assessing saved time trough specific unit costs for each vessel category

This method corresponded to CBA analysis carried out for land transport projects; to find the future demand and the saved travel and waiting time and to assess the savings using a general value of time.

In the pre-tunnel situation, the travellers make two kinds of adjustments which are not included in the current recommended method:

- They adjust the speed to the weather conditions to reduce the probability of an accident.
- They wait until daylight to pass Stad to improve their chances if an accident occurs.

1.2 Stad and the sea tunnel

Stad is a long narrow peninsula on the western coast of Norway (Figure 1). The idea of a sea tunnel for ships through the peninsula is more than 100 years old. A tunnel is expected to make the trip past Stad safer and faster in bad weather.

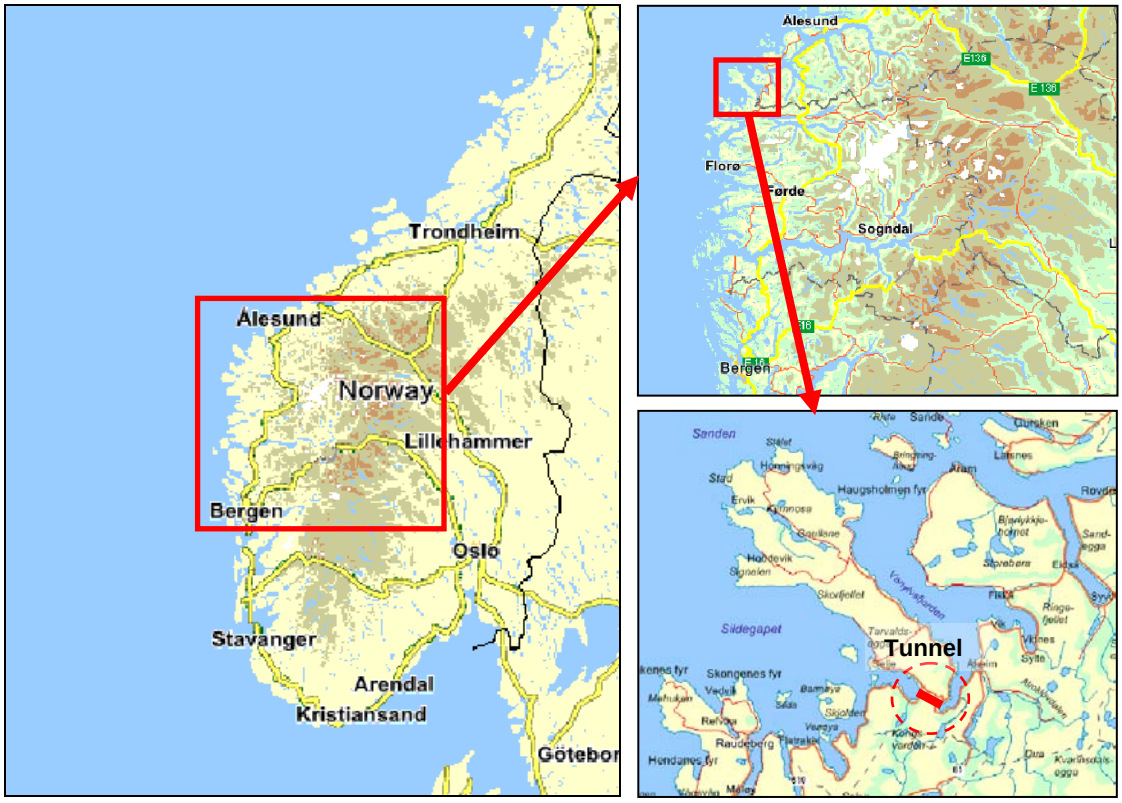

Figure 1: Stad (maps from www.gulesider.no\kart)

Weather and sailing conditions:

The waters just outside the Stad peninsula are very unpredictable. The floor conditions with shallow banks close to shore and much deeper sea farther out, result in waves breaking in several directions, causing rough and difficult sailing conditions. The difference in depth can also create difficult waves long after heavy weather. This is often a surprise to the visiting seafarers who typically only take the current wind conditions into account when they consider to cross the Stad waters or not. The dangerous and unpredictable sailing conditions represent a huge barrier for smaller boats. The larger vessels would typically choose a shipping lane further out at sea where the water is deeper and the waves more predictable.

There are considerable seasonal variations; the weather and sailing conditions are less of a problem during summer, but a major problem during winter (October - March). The smaller the vessel is, the bigger the problems are. The larger pleasure crafts would typically have problems with wind force of Strong breeze or more, which occurs roughly every second day throughout the year (Table 1). The commercial fleet experience problems with winds at Near gale/Gale and stronger from the west (roughly every 3rd day

on average). The duration of the wind is important; a few hours of wind does not represent a big problem, whereas a day or more could be a major problem. The wave heights increase with increasing duration of strong winds. The conditions are worse for southbound than for northbound traffic.

Table 1: Wind force measured at Svinøy lighthouse, 2000-2006 (source: DNMI)

	Number of days with wind force at least...						
Year	Strong breeze (10.8-13.8 m/s)	Near gale (13.9-17.1 m/s)	Gale (17.2-20.7 m/s)	Strong gale (20.8-24.4 m/s)	Storm (24.5-28.4 m/s)	Violent storm (28.5-32.6 m/s)	Hurricane (32.7+ m/s)
2000	212	135	70	33	18	5	1
2001	183	121	63	30	9	1	0
2002	180	111	69	33	11	3	1
2003	198	132	84	35	15	3	0
2004	196	132	87	37	13	2	0
2005	185	134	74	27	5	0	0
2006	165	116	82	41	17	1	0
Mean	188	126	77	35	12	2	0

Traffic and accidents

In 2006 some 26 000 vessels entered the waters at Stad in a north- or southbound direction (Table 2). These figures are based on data from a variety of sources:

- AIS (Automatic Identification System) - in Norway compulsory for all tankers and passenger vessels, and for other vessels exceeding 300 BT[1]
- Satellite tracking (GPS) of all fishing vessels of length 45 m or more
- Sailing plans for passenger vessels in schedule
- National freight model (Meland et al., 2005)
- Interviews with marina owners in the surrounding Stad

Table 2: Sailings past Stad, 2006

Vessel type	*N*	*%*
Coastal express (scheduled passenger line)*	730	3 %
Other passenger ships†	330	1 %
Pleasure crafts (estimate)**	6 000	23 %
Tankers†	2 520	10 %
Fish carriers†	620	2 %
Bulk carriers†	1 630	6 %
General cargo carriers†	7 290	28 %
Fishing vessels***	5 380	21 %
Other vessels†	1 520	6 %
TOTAL	26 020	100 %

† Based on AIS-data
* Based on sailing schedules
** Based on interview with marina-operators in the area.
*** Based on data from AIS, GPS tracking and estimates from freight model

With this many ships in the allegedly dangerous waters, one would expect a large number of accidents and incidents. For the years 2001-2006 there was a total of 81 reported

[1] http://www.imo.org/Safety/mainframe.asp?topic_id=754

incidents in the waters near Stad (Kystverket, 2007b), i.e. some 13-14 per year. Almost half of these were related to vessels requiring assistance, while an average of two per year had to do with vessels running aground.

The, perhaps surprisingly, low number of incidents and accidents does not reflect the actions the seafarers take to avoid potentially risky situations, even if it sometimes comes with a cost. If these actions were not taken, and the seafarers treated Stad as they do with most other parts of the Norwegian coastline, the number of accidents and unwanted events would probably be much higher, with costs potentially far outweighing the costs currently included in the CBA.

Stad sea tunnel

The CBA was carried out to evaluate a tunnel through the Stad peninsula. Two alternatives dimensions were suggested (Table 3, Figure 2). The larger tunnel alternative is designed to let the Coastal Steamer through.

Table 3: Size of the alternative tunnels

Measured value	Large alternative	Small alternative
Sectional area	1 625 m²	1 000 m²
Sailing depth	8.0 m	8.0 m
Sailing height	32.5 m	22.4 m
Sailing width	21.5 m	18.0 m
Tunnel length	1 700 m	1 790 m

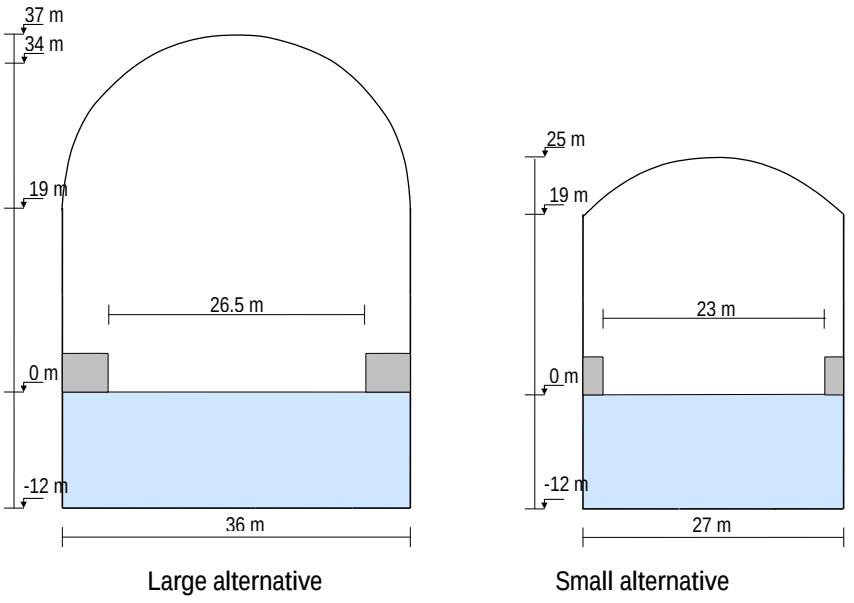

Figure 2: Sectional areas measures, tunnel alternatives

Construction costs are approximately EURO 250 and 160 million respectively for the two alternatives, and the opening year was assumed to be 2014.

2 Interviews and open meetings

Among the sources of information about possible consequences of the tunnel, were the open meetings arranged by the NCA and a series of interviews made by SINTEF.

Open meetings

Two meetings with the public and other interested parties were arranged during our work with the CBA. Both were held in Ålesund, a city north of Stad (se right, upper map in Figure 1). On the first open meeting, the project was presented with the proposed alternatives. On the second open meeting the preliminary results from the CBA was presented.

The open meetings were visited by about 50 people each, among them representatives from political parties, the rescue service, the coastal steamer, the pilot service, the freight ships, the fisheries and the local industry. The purpose of the meetings was to get feedback from the public on the suggested alternatives and on the assumptions made in the CBA.

The feedback from the people directly and indirectly affected by the difficult sailing conditions at Stad, made a strong impression. They gave valuable information about how a tunnel would change their everyday situation.

Telephone interviews

The shipping companies were contacted for information about their decision rules regarding when to cross Stad and when to wait for better weather conditions and the consequences of these decisions. The Marinas were contacted to get information about the leisure vessels. The cargo owner was contacted for information about damage to the cargo and their potential use of a tunnel.

Table 4: Interviewees

Interviewee	N	Representing N. sailings at Stad per year
Shipping company, freight	6	1 750 - 2 000
Shipping company, tourism	1	
Fishing organisation	1	some 5 000
Marina	3	some 6 000
Cargo owner	1	600-800

Validity of the information

The information from the open meetings and interviews comes from a small number of people – less than a hundred people all in all. We did not carry out a systematic research to find out about missing effects, but the response from the different people we talked to, gave a general idea of reactions to a fear level that were omitted from the CBA method.

3 Information from the open meetings and the interviews

Some of the main findings from the open meetings and interviews are presented below.

The fishing fleet

The smack fleet passes Stad infrequently, while the larger vessels (13m +) pass Stad at a regular basis.

The fishing vessels usually follow the coast as far as possible before heading for the offshore fishing grounds. The Stad peninsula is in practice a barrier for delivery of their catch; the fleet avoids passing Stad with their catch, as it may be damaged and suffer a loss of value. A tunnel will open for a larger market for the delivery of catch. This is expected to result in more competition between the buyers, and higher prices for the catch.

Other commercial traffic

The shipping companies with the highest number of ships passing by the Stad peninsula (as registered in the AIS data), were interviewed by phone. The focus of the interviews were the potential use of the tunnel under varying conditions, and an assessment of what benefits the company could gain from using the tunnel.

- Sensitivity towards weather conditions depends on type of cargo carried on board. This includes risk of cargo shifting and causing the vessel to list, and risk of damage to cargo. Bad weather conditions during winter may cause problems with deck cargo.
- Parts of the fleet traverse the waters at Stad independent of the weather conditions. In case of extreme weather, the vessels use an outer lane, further out at sea. The speed is significantly reduced - frequently halved, and in extreme cases the speed over ground is reduced to zero.
- In case of bad weather conditions, vessels carrying general cargo / dry cargo tend to wait for daylight before entering the waters in the Stad area. This is done to reduce risk of accidents, and to ease the rescue operation in case of an accident occurring.
- A tunnel is expected to provide more predictable sailing conditions and improved punctuality. This will allow some companies to guarantee agreed delivery times, and thus to attain higher freight rates. The possibility to guarantee delivery times is also expected to strengthen the competitiveness of sea transport vs. road transport.
- The shipping companies are usually unaware of the value, vulnerability or insurable value of the cargo they carry. An increased information level about the cargo properties might lead to changes in the decisions about whether to use the tunnel or not. This might alter the rentability of the tunnel, but it is not obvious in which direction.

For almost all the shipping companies, the three main expected gains from a ship tunnel were stated to be (in varying order):

- Time savings and improved punctuality
- Safer sailing
- Less strain on vessels, equipments and crew

Pleasure crafts
Estimates suggest that a minimum of 6 000 pleasure crafts pass by Stad every year, mainly during the summer season. Owners of marinas which serve as waiting harbours (in anticipation of suitable sailing conditions) in the area state that:

- Due to the sailing conditions, small vessels can round Stad only a few days per year (during the summer season).
- Cabin cruisers of 25' and more have to wait for better conditions during wind forces of Strong breeze or more, or when the wave height is 2 m or more. Ocean racers can usually take somewhat rougher conditions.
- Waiting for suitable sailing conditions can take several days – some have been waiting for more than a week. For most tourists this is not an option, as the number of days of vacation is limited.
- Roughly 1 000 of the pleasure crafts follow the scheduled escort vessels round Stad, operated by the Norwegian Society for Sea Rescue (NSSR).
- If the weather is bad, many of the pleasure crafts turn around at Stad. Even if the weather conditions are good, many choose not to continue past Stad as they do not know what the conditions will be like when they return.
- Since the local lighthouse (Svinøy) was automated, it is no longer possible to get real time information about the conditions at Stad.
- It is not uncommon that family members are sent by land transport (bus or even bicycle) past Stad, while only the necessary crew is left on board to take the vessel through the dangerous waters.

Loss of welfare
In addition to the description of various types of actions taken to reduce the risk of travelling in the waters around the Stad peninsula, there were reports on how Stad creates anxiety not only among the people actually aboard the vessels crossing these waters, but also among family members, ship owners and the people living along this part of the coastline. The weather forecasts are followed closely, and when ships have to cross at night, the mobile phone is placed on the bedside table - with a hope that it will not ring.

4 Discussion

4.1 Does CBAs for sea-related safety projects have special requirements?

Findings from the Stad analysis suggest that the seafarers differ from road users in the way they relate to safety and risk. They actively consider and adapt to the sailing conditions to keep the perceived risk at a minimum. Based on current sailing conditions, they consider:

- whether to sail by Stad or not
- when to sail
- speed
- choice of destination/port
- route choice

In addition, there is information that some cargo owners and hauliers avoid using sea-transport for shipments passing Stad, in fear of potential damage to the cargo.

The efforts to avoid dangerous situations are only partially represented in the CBA
If the Stad tunnel is built, the seafarers will not have to make these precautions, and they could behave there as they would in less dangerous waters. This is a very different situation compared to analysis of road infrastructure projects. It is not common to see road users avoid a certain route or make other major adjustments to reduce risk, although this might be the case for travellers using roads exposed to rockfall or avalanches, or pedestrians/bicyclists relating to roads and crossroads with heavy traffic. In most cases, the drivers might consider reducing the speed at accident black spots, but the adjustments would usually be minor compared to what has been found among the seafarers in the Stad area. This indicates a difference between sea and land transport which is not included in CBAs so far. Some of these efforts are quantified and valuated in terms of waiting time and travel time in the CBA, while other aspects are not captured at all.

This is an area with need for more research, in order to better adapt the CBA methodology to the specific characteristics of sea transport.

Should "hidden accidents" be included in the CBA?
By making these efforts to avoid potentially dangerous situations, the seafarers are internalising some of the "costs" related to avoiding accidents.

In public transport planning, the term "hidden waiting time" is used for the waiting time the passenger spends before leaving the indoors to catch the bus. The waiting time spent at a bus stop is easily identified as "time spent waiting for the bus", and can be observed and quantified. The hidden waiting time - the time between the ideal and actual time of departure - is often utilised for other activities, blurring the fact that this actually is a part of the total waiting time related to the public transport service in question.

Similarly, it may be worthwhile to consider introducing the term "hidden accidents" in relation to safety measures at sea. All the various actions being taken by the involved parties in order to avoid dangerous situations can be considered substitutions for accidents which would have happened if the extra precautions had not been taken.

How can near-accidents be included in the CBA?
Accidents in the CBA include events where people are physically injured or goods are damaged or have a reduced value as a consequence. The outcome of other incidents, such as near-accidents, are not included in the CBA. Near-accidents can be understood as events or incidents which easily could have had serious consequences, but the outcome was no material damages or they were insignificant. However, rescue-operations in the case of near-accidents can be large-scale, and come with a considerable cost. One example of this is the near-accident with the coastal express ship Midnatsol in December 2003. Huge efforts were made in order to prevent a major disaster, and as the effort succeeded, the costs related to this operation are not included in the CBA.

Willingness to pay for safety improvements
If there is willingness to pay for avoiding dangerous situations and near-accidents, this element should be considered included in the CBA analysis. The total willingness to pay could give a good basis for assessing efforts to reduce the number of accidents and near-accidents.

The actions taken by companies and people to avoid dangerous situations, and to minimize consequences, are likely to lead to fewer accidents and near accidents, and give less serious consequences of the actual accidents. If the new tunnel reduces the feeling of risk or danger passing Stad, some of these actions will not be taken anymore, and the savings should be shown in the economic calculation.

Welfare loss due to the general levels of perceived danger
All involved in or in the vicinity of the shipping activities at Stad suffer a more or less "permanent welfare loss". Welfare loss is included in the accident analysis, but then only in relation to actual accidents. Should - and could - welfare loss resulting from frequently recurring anxiety related to difficult weather- and sailing-conditions be included in a CBA?

Does the CBA method render justice to the commercial traffic?
The CBA methods applied was developed for road projects, where commercial vehicles usually represent only a small fraction of the total traffic. At sea the ratio commercial/private may be very different, with the commercial activities dominating. Does the dominance of commercial traffic at sea have implications for the methodology and cost structure used in the CBA?

Can the findings from the Stad study be generalised to sea transport in general?
According to NCA, there are similar findings related to another project in "open sea", while for projects related to harbours and basins, the shortcomings of the CBA method seem to be less of a problem.

4.2 Similar projects for land transport

Even though the Stad tunnel as an infrastructure project deviates from infrastructure projects for road transport, there are situations also in road transport where the road users might take precautions because they have an increased perceived fear level. Driving on an icy road is one example, but fortunately many drivers take actions and drive according to the prevailing driving conditions. This is a situation where infrastructure projects would not remedy the situation. Another example is mentioned in the handbook from the NPRA, and covers insecurity for people walking and biking alongside a road or crossing a road with heavy traffic (Statens vegvesen, 2006). Relevant infrastructure projects could be a dedicated lane for pedestrians or bicycles or traffic lights at crossings. A third example might be roads exposed to rock falls or avalanches. A tunnel would eliminate the risk. Precautions taken by the people might be similar to the ones presented in this paper; not to go and even holding back pupils from school, choose a different path or a safer mode if possible.

4.3 Importance of the described effect

The described effects of the perceived fear level are not studied in detail through our work with the CBA of a Stad tunnel. One of the near accidents illustrates why these effects are important: In 2003, one of the coastal steamer had failure on both engines just outside Stad. This incident was the direct reason why a new and larger sectional area for the tunnel was proposed. This indicates that these effects are important, and might even shift the rentability of the project. As a consequence of the experiences made in this project, we recommend that the missing effects should thus be explored in more detail.

5 Conclusions

The method used for CBA of safety projects at sea should be altered to include direct and indirect costs related to precautions taken to avoid risk. Via open meetings and telephone interviews a range of different stakeholders have described the precautions they take because of the difficult sailing conditions at Stad. The actions they currently take, imply costs which should be included in the CBA. A further study should be carried out to explore the described effect more thoroughly, to quantify the effects in this and other similar projects, and to express them in monetary terms.

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