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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1. Introduction

This paper is based on findings from the work with a Cost Benefit Analysis (CBA) completed for a sea tunnel for ships. The project was financed by the Norwegian Coastal Administration (NCA), and was carried out during 2007.

The work has revealed that the precautions and adaptations the seafarers make to avoid dangerous situations at sea, are not sufficiently reflected in the CBA method used.

The work included interviews and public open meetings with seafarers and other parties interested in the Stad tunnel. Participants told about what measures are taken in order to avoid dangerous situations. Stad is known among all seafarers along the Norwegian coast for its dangerous waters. They take precautions today that they would not have to 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.

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 for a long time after rough winds. This is often a surprise to the visitor seafarers who typically only take the current wind conditions into account when they consider where they choose to go. The dangerous and unpredictable sailing conditions represent a huge barrier for the smaller boats. The larger vessels would typically choose a shipping lane further out in the sea where the sea is deeper and the waves more stable.

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, the bigger the problems. The larger pleasure crafts would typically have problems with wind force of Strong breeze or more, which occurs roughly half of the days per year (Table 1). The freighter 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 is not a big problem, while a day or more could be a major problem. The wave heights increases with increasing duration of strong wind. The conditions are worse for southbound than for northbound traffic.

<table>
<thead>
<tr>
<th>Year</th>
<th>Strong breeze (10.8-13.8 m/s)</th>
<th>Near gale (13.9-17.1 m/s)</th>
<th>Gale (17.2-20.7 m/s)</th>
<th>Strong gale (20.8-24.4 m/s)</th>
<th>Storm (24.5-28.4 m/s)</th>
<th>Violent storm (28.5-32.6 m/s)</th>
<th>Hurricane (32.7+ m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>212</td>
<td>135</td>
<td>70</td>
<td>33</td>
<td>18</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>2001</td>
<td>183</td>
<td>121</td>
<td>63</td>
<td>30</td>
<td>9</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2002</td>
<td>180</td>
<td>111</td>
<td>69</td>
<td>33</td>
<td>11</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>2003</td>
<td>198</td>
<td>132</td>
<td>84</td>
<td>35</td>
<td>15</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>2004</td>
<td>196</td>
<td>132</td>
<td>87</td>
<td>37</td>
<td>13</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>2005</td>
<td>190</td>
<td>134</td>
<td>74</td>
<td>27</td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2006</td>
<td>165</td>
<td>116</td>
<td>62</td>
<td>41</td>
<td>17</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Average</td>
<td>188</td>
<td>126</td>
<td>77</td>
<td>35</td>
<td>12</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

Traffic and accidents
In 2006 some 26 000 vessels entered the waters at Stad in a north- or southbound direction (Table 2).

<table>
<thead>
<tr>
<th>Vessel type</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coastal express (scheduled passenger line)</td>
<td>730</td>
<td>3 %</td>
</tr>
<tr>
<td>Other passenger ships</td>
<td>330</td>
<td>1 %</td>
</tr>
<tr>
<td>Pleasure crafts (estimate)</td>
<td>6 000</td>
<td>23 %</td>
</tr>
<tr>
<td>Tankers</td>
<td>2 520</td>
<td>10 %</td>
</tr>
<tr>
<td>Fish carriers</td>
<td>620</td>
<td>2 %</td>
</tr>
<tr>
<td>Bulk carriers</td>
<td>1 630</td>
<td>6 %</td>
</tr>
<tr>
<td>General cargo carriers</td>
<td>7 290</td>
<td>28 %</td>
</tr>
<tr>
<td>Fishing vessels</td>
<td>5 380</td>
<td>21 %</td>
</tr>
<tr>
<td>Other vessels</td>
<td>1 520</td>
<td>6 %</td>
</tr>
<tr>
<td>TOTAL</td>
<td>26 020</td>
<td>100 %</td>
</tr>
</tbody>
</table>
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 incidents in the waters near Stad (Kystverket, 2007), 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 reflect the actions the seafarers take to avoid potentially risky situations, even if that sometimes comes with a cost. If these actions were not taken, and the seafarers acted at Stad as they do along 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 and Figure 3). The biggest tunnel is designed to let the Coastal Steamer through.

<table>
<thead>
<tr>
<th>Measured value</th>
<th>Big tunnel</th>
<th>Small tunnel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sectional area</td>
<td>1 625 m²</td>
<td>1 000 m²</td>
</tr>
<tr>
<td>Sailing depth</td>
<td>8.0 m</td>
<td>8.0 m</td>
</tr>
<tr>
<td>Sailing height</td>
<td>32.5 m</td>
<td>22.4 m</td>
</tr>
<tr>
<td>Sailing width</td>
<td>21.5 m</td>
<td>18.0 m</td>
</tr>
<tr>
<td>Tunnel length</td>
<td>1 700 m</td>
<td>1 790 m</td>
</tr>
</tbody>
</table>
Construction costs are approximately €250 and 160 million respectively for the two alternatives, and the opening year was assumed to be 2014.

### 3. Reactions to dangerous waters – experience from Stad CBA

Information was gathered from a wide range of stakeholders - shipping companies operating local, national and/or international freight or passenger lines in the area, local authorities, industry, tourist businesses, marinas, rescue vessels, local captains’ and pilots’ associations, etc. The information was collected through telephone interviews and in public information meetings about the Stad tunnel. Some of the main findings 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 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 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 outer lane, further out at sea. The speed is significantly reduced - frequently halved, and in extreme cases the speed 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 or insurable value of the cargo they carry. This is only made known in case of damages and insurance claims, which occur rarely. One of the main reasons for the ships to wait for better weather conditions, is to avoid damages to the cargo.

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 5 000 pleasure crafts sail 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 to 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 last for 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 (Svinoey) 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. Components of the CBA
The method used to carry out CBAs for public investment projects at sea is more or less a blueprint of the method used by the Norwegian Public Road Authorities (NPRA) in evaluating projects concerning land-based traffic.

The CBA consists of components which are assessed with official costs (quantitative factors), and components with no set cost attached to it (qualitative factors).

The quantitative factors include:
• Changes in time-use, travel length and monetary costs
• Changes for passenger boat operators
• Changes in accident cost
• Public investments
• Remaining value
• Taxation efficiency loss

The qualitative factors include:
• Landscape
• Outdoor life
• Natural environment
• Cultural environment
• Fish and aquaculture
• Noise
• Comfort, security, safety
• Tourism
• Passenger transport
Components of an accident analysis
The accident analysis in a CBA for The Norwegian Coastal Administration consists of the following components¹:

- Fatalities
- Personal injuries
- Material damage on vessels
- Damage on or loss of cargo
- Costs connected to salvage, elevation and/or draining of vessels
- Costs connected to vessels being out of operation after an accident
- Costs connected to rescue operations

The descriptions of each of the components are extended compared to the method used by the NPRA, in that material damages are described in more detail in the NCA Guide. The consequences of Fatalities and Personal injuries are treated more or less the same way.

The unit costs include both costs in real terms and welfare loss (CBA Handbook). 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 may imply that anxiety and fear following an accident is included, but it is not obvious from the description.

Near-accidents are not included in the CBA today, as risk is calculated as the product of frequency and consequence.

The difference between the quantitative and the qualitative impacts in the CBA
As mentioned, the CBA includes impacts which are assessed with or without a set unit cost. Essential questions in a CBA would be:

- Which effects of the project should be included?
- How should the effects of the project be assessed?

Impacts assessed with a monetary cost are often the kind of impacts that are included in every CBA, and which have official costs. Impacts with no set monetary value may vary from project to project, and may be the object of more qualitative valuation, typically with a classification of the sign (positive/negative) and magnitude of the impact. In this situation, the planner and the decision makers need to weigh these “qualitative” impacts up against “prized” impacts.

This leads to a situation where the impacts in reality are assessed differently in each project evaluation, and the assessment of the qualitative impacts could become more subjectively evaluated than the quantitative impacts. This is a consequence of the method used, and is probably unavoidable. Since the qualitative impacts tend to differ from project to project, it may be considered not worthwhile to make studies of the willingness

¹ The Norwegian Coastal Administration (NCA): Guide to socioeconomics analysis (Guide CBA), 2007, page 54, table 6.8
to pay for each of them. Also, in many project evaluation plans there is no need to do that, since they in any case will be outweighed by other impacts.

If a qualitative impact of a project is very important or decisive for or against the project or between alternatives, one should try to find more objective ways to evaluate the impacts, if it is possible. Time pressure is not a good argument to not find reasonable criteria.

Quantitative impacts can be evaluated more objectively than the qualitative impacts, since the same elements tend to be included in every CBA. The analysis of impacts which come with a monetary value can therefore reflect benefits for society from the project in a better way than when the impacts are not assessed in monetary terms. This does not mean that qualitative impacts should be excluded, but as far as possible, all important impacts should be clarified and valuated in monetary terms.

5. Does CBAs for sea-related 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
- 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 hurt or goods are damaged or have a reduced value as a consequence. The outcome of other incidents such as near-accidents is not included in the CBA. Near-accidents can be understood as events or incidents which easily could have given 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 to avoid 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 the companies and the people to avoid dangerous situations, and to minimize consequences, are likely to lead to fewer accidents and near accidents, and give less serious consequences. 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 an other 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.

**References**