REPORT

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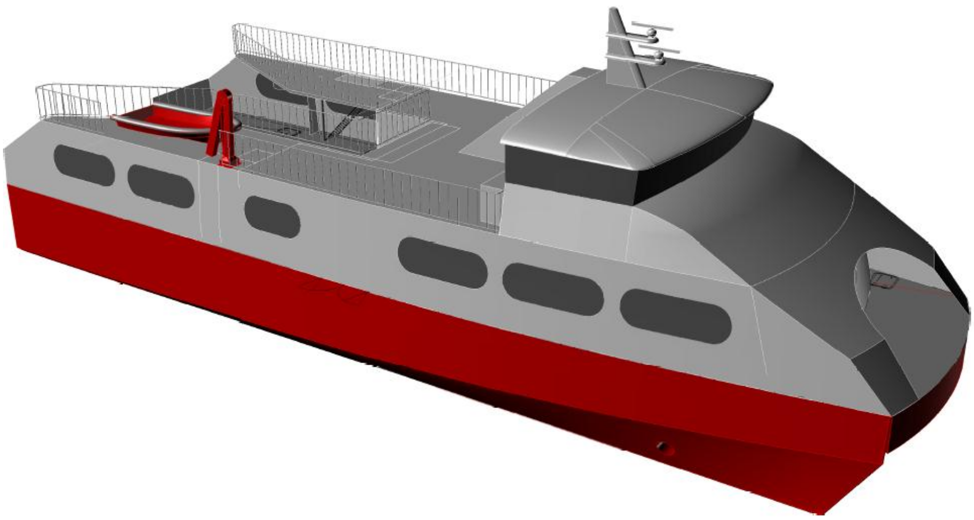
Life Cycle Cost Analysis - Eco-Island ferry

(3 appendices)



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1 Background

This life cycle cost analysis is a part of the Eco-Island ferry project, investigating the potential for *eco*nomic and *eco*logical lightweight ferries in Sweden and Denmark. The life cycle costs of a new light-weight ferry and a conventional steel ferry are compared.

1.1 Background to the Eco-Island ferry project

After a meeting in the EU project MARKIS, an industrial group from northern Denmark and SP, the technical research institute of Sweden, started to discuss production of displacement ferries with reduced environmental impact. This led to a Swedish-Danish consortium with the objective to open up for the construction of this type of ferry in the Swedish and Danish region. The project was given the name "Øko-Ø-færge" (Eco-Island ferry translated to English) and a project group was formed consisting of naval architects from Sweden and Denmark, university representatives and specialists from research institutes. According to the project plan, a full fire safety assessment according to SOLAS [1] chapter II-2 as well as LCC and LCA assessments should be carried out. The LCC assessment is presented in this report.

A preliminary study financed by Västra Götlandsregionen was performed by SP Technical Research Institute of Sweden [2]. The preliminary study included investigations of national, European and international fire safety regulations, but also investigations of the financial potential and potential market for lightweight island ferries in the region. Search for further funding was also included in the study, which was allocated by the Danish Maritime Fund, as well as design of the light-weight "Eco-Island ferry". The new ferry is meant to illustrate how island ferries can be replaced by new and more ecological and economical alternatives. In the project the Eco-Island ferry was therefore set out to replace the old Tun Island Ferry (*Tunøfærgen* in Danish), which travels a route between Hov and Tunø in Denmark. The new ferry was to keep the same capacity as the Tun island ferry with 200 passengers and 6 cars. Using Fibre Reinforced Polymer (FRP) composite as shipbuilding material it is possible to reach a weight reduction of up to 60% [3] compared to a conventional steel ferry. With decreased fuel consumption this would reduce both operational costs and environmental footprint.

1.2 Objective

The objective of this study is to make a comparative life cycle cost analysis between two different ferries. The first investment option is the newly designed Eco-Island ferry, and the second option is to build a new steel ferry identical to the existing Tun island ferry. The two ferries are presented in Chapter 2.

2 Reference object

The reference case selected for this project is the *Tun island ferry* (or *Tunøfærgen* in Danish) which is a Ro-pax ferry class D from 1993, designed to carry about 6 cars and 200 passengers (IMO number 9107875). It travels a route between Hov and Tunø on the east coast of Denmark, a trip that takes approximately 1 hour one way. Approximately 50 000 passengers travel with the ship each year.

The Eco-Island ferry has been designed with the same capacity as the Tun island ferry and approximately with the same dimensions. They are both displacement ferries with a designed cruise speed of 9.5 knots. However, the Tun island ferry is a steel ferry and the Eco-Island ferry has been designed with significantly lighter materials, which implies decreased fuel consumption thanks to lower engine power needed (220kW compared to 590kW). The two ferries are shown in Figure 1 below.

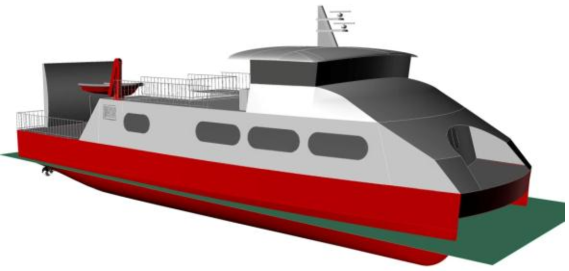

Figure 1. The existing Tun island ferry (photo: www.tunøfærgen.dk) to the left and the Eco-Island ferry to the right (photo: Danish Yacht).

The dimensions of the ferries are approximately 30.7 x 10 x 1.4m (Length x Width x Draught), and general characteristics are found in Table 1 below.

Table 1 Weight specification for the Tun island ferry and the Eco-Island ferry

Weight item	***Tun island ferry [kg]***	***Eco-Island ferry [kg]***
Lightweight	250 000	72 000
Ballast	33 900	0
Fuel & water	18 800	8 000
Stores	1 000	1 000
Passengers	15 000	15 000
Crew	225	225
Luggage	2 000	2 000
Cars	16 000	16 000
Deck cargo	3 075	3 075
Displacement	**340 000**	**117 300**

3 LCCA

LCCA stands for Life Cycle Cost Analysis and is sometimes referred to as LCC analysis. It is often used to compare different investment possibilities in order to select the most profitable alternative.

The life cycle cost analysis aims to consider all the cost factors during the operational life of an item, beginning when the acquisition is first considered and ending when it is taken out of service.

Life cycle costs analyses can be used for describing both environmental costs and economic costs. In this report, only the economic costs are studied.

In the previous research project LASS [3], light-weight construction applications at sea, different uses of composite in maritime applications were investigated in life cycle analyses [4].The method developed for LCC analysis has been used as basis for the approach of the current LCCA.

3.1 Description of LCCA

This LCCA is based on the model described by Woodward [5].

In the original model, an eight-step approach is outlined:

1. Establish the operating profile
2. Establish the utilization factors
3. Identify all the cost elements
4. Determine the critical cost parameters
5. Calculate all costs at current prices
6. Escalate current costs at assumed inflation rates
7. Discount all costs to the base period
8. Sum discounted costs to establish the net present value.

In this study the operating profile is supposed to be the same as for the existing Tun island ferry. The utilization factors are the reduced needs for fuel and maintenance, which results in lower running costs. The cost elements are divided into four parts; initial costs, production costs, operation and maintenance costs and disposal costs. The critical cost parameters mentioned in step number 4, for example downtime, are not included in this study. The costs are calculated at current prices, and escalated and discounted.

This is a comparative analysis, meaning that costs that are expected to be the same for both options are not included. An example of such costs are salaries, since the number of the crew are expected to remain unchanged. No research regarding the income has been made as the ferries are expected to take the same number of passengers, and therefore generate the same income.

In the original model, the life cycle cost study has a cradle-to-grave perspective. However, in this study the two compared ferries are supposed to have different technical life-times. The end of the study is therefore set after 20 years of operation, and instead of having disposal costs at the end of the life cycle, a rest value is used.

In reality, the costs are spread over the entire year, but in the analysis all costs are assumed to take place at the end of the year.

3.2 Time value of money

The value of money is time dependent, meaning that money spent in the future will not have the same value as if spent today. Due to inflation, the value of money will decrease with time. But the value of well invested money will grow, resulting in a higher value in the future.

When calculating the costs in a life cycle analysis, it is important to consider when the money is spent. The costs (production costs, fuel cost etc.) are estimated at current prices. Thereafter, the future costs at year *t* are calculated with consideration to the inflation rate, using eq. 1:

$$Future\ cost = Current\ price\ (1 + inflation\ rate)^{t} \qquad \text{(Eq. 1)}$$

The future cost is thereafter discounted back to the present value, meaning the amount of money needed today for paying the cost in the future, including the interest rate.

$$Present\ value = Future\ cost\ (1 + interest\ rate)^{-t} \qquad \text{(Eq. 2)}$$

By combining eq.1 and eq.2, eq.3 is obtained:

$$Present\ value = Current\ price\ (1{+}inflation\ rate)^{t}\ (1{+}interest\ rate)^{-t} \qquad \text{(Eq. 3)}$$

3.3 Break-even analysis

The costs are spread over the whole life cycle, starting with initial costs and production costs, followed by operation costs and finally a rest value. When comparing different alternatives, the so-called break-even point is the time when the sum of the costs for the different options is equal.

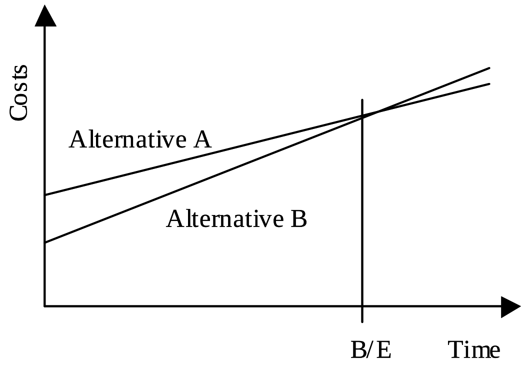

Figure 2 Illustration of accumulated costs and break-even point [4]

An illustration of the break-even point is shown in Figure 2. The break-even point is important when choosing between the options. If the break-even time is short, it may be more interesting to choose the option with higher investment cost but lower operational cost.

4 Data for the LCCA

After the start of the project costs are spread over the whole time span of a life cycle. The costs are assumed to be distributed over time as follows:
The first year, the initial costs for planning, design and development occurs. The second year the ferries are manufactured and the production cost appear. The ferries are taken into operation the third year after the start of the project. Hence the third year has operation costs, but no maintenance is assumed to be needed the first year in operation. From year four and forward both operation costs and maintenance costs occur yearly. After 20 years of operation, which is the time frame of this analysis, the rest values of the ferries are approximated.

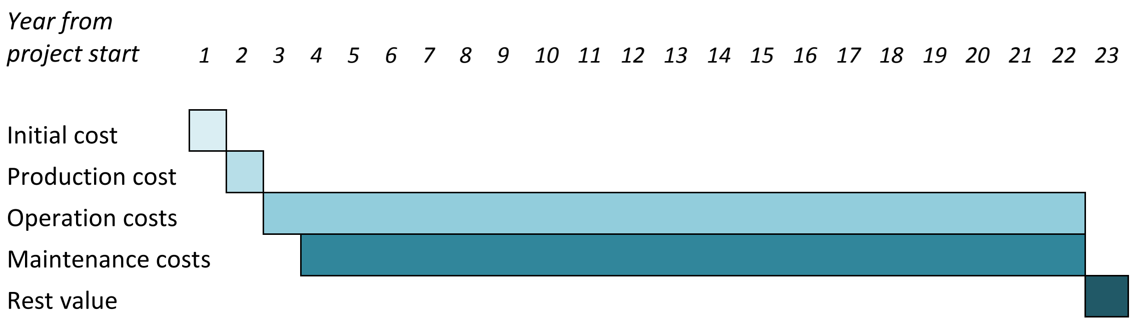

Figure 3 Distribution of costs during the ship life cycle

As mentioned earlier, this is a comparative analysis. This means that not all costs are included, but only the costs that are expected to differ between the different options. It is therefore not the total initial costs, production costs or operation costs that are presented in the following chapters, but only the costs that differ between the Tun island ferry and the Eco-Island ferry.

4.1 Interest rate, inflation rate and exchange rate

Care must be taken when choosing the different rates. A high inflation rate will make costs that occur in the distant future more expensive, benefitting the option with lower future costs. On the other hand, a high interest rate will favour the option with the lowest investment cost.

The inflation rate used is the average inflation rate in the Euro area for the years 2000-2011, which is 2,1% [6].

The interest rate can be debated. The interest rate could be chosen as the revenue from other investment options, at least saving money on a bank account. But it is also possible when a larger investment is to be made that money must be borrowed from the bank. The interest rate chosen is based on Euribor, Euro Interbank Offered rate. This is the rate at which European banks lend money to each other. The average Euribor 1-year rate from 2000-2011 is 3.1% [7]. A slightly higher interest rate of 4% is used in this analysis.

The used exchange rate between Euro and Danish currency is the average value from April 2011-March 2012, and is € 1.00 = 7.46 DKK [8].

4.2 Initial costs

The initial costs include costs for design and development, and different equipment for manufacturing. Those costs are supposed to be the same for both options. The only difference taken into account is that the composite ferry will need a fire safety analysis to fulfil the requirements in Regulation 17 in SOLAS [1]. The cost of the analysis is approximated to 1 MDKK.

Table 2 Initial costs for the Tun island ferry and the Eco-Island ferry

	Tun island ferry	Eco-Island ferry
Initial cost [M€]	0	0,13

4.3 Production costs

The production cost for the steel ferry was estimated from the production cost of the existing Tun island ferry, which was built in 1993. Today's production cost is estimated to 34 MDKK.

The production cost for the composite ferry was estimated by Danish Yacht, and is approximated to 40 MDKK, including the fire safety analysis put under initial costs.

Table 3 Production costs for the Tun island Ferry and the Eco-Island ferry

	Tun island ferry	Eco-Island ferry
Production cost [M€]	4,6	5,2

The production costs do not include costs for furniture etc., but that is assumed to be the same for both ferries.

4.4 Operation and maintenance costs

In operation costs, only fuel costs and electricity costs are included. No salaries are included, since they are supposed to be the same for both ferries.

4.4.1 Fuel and electricity costs

The fuel costs will depend on the operating time, the fuel consumption of the ferry and the fuel price.

The operating time is estimated from the timetable for the existing Tun island ferry. The ferry travels to Tunø and back about 700 trips per year, corresponding to about 2 trips/day. One return trip includes 2 operational hours. The operating time is supposed to remain unchanged during the time period of the life cycle analysis. The impact of the operating time for the final results can be found in Chapter 6.2, sensitivity analysis.

The fuel consumption for the Tun island ferry is based on data for the existing ferry and the consumption for the Eco-Island Ferry is based on data from the ship yard.

Table 4 Fuel consumption for the Tun island ferry and the Eco-Island ferry at a speed of 9.5 knots

Fuel consumption	Tun island ferry	Eco-Island ferry
Main engines per hour at 9.5 kts [litre]:	90	41.4
Genset pr. hour (HVAC-EL-bowthruster) [litre]:	10	11.7
Length of each tour [h]:	2	2
Fuel consumption of each tour [litre]:	*200*	*106*
Number of voyages per year:	700	700
Consumption per year at voyages [litre]:	*140 000*	*74 340*
Consumption in harbour per year (HVAC) [litre]:	*8792*	*0*
Total fuel consumption [litre/yr.]:	*148792*	*74340*

From Table 4 it can be seen that the yearly fuel consumption for the Tun island ferry is twice the predicted consumption for the Eco-Island ferry.

The fuel price is based on the current fuel price for the Tunø ferry. The fuel price might change in the future and different scenarios will be investigated in the sensitivity analysis, see section 6.1. The fuel price used is 0.8 euro per litre (excluding VAT). In the last 20 years, the fuel price has increased about 3% yearly excluding inflation. An yearly increase in the fuel price of 3% in addition to the inflation is therefore used as the base case in the life cycle cost calculations.

The electricity consumption in harbour will differ between the two ferries, since the Eco-Island ferry will use electricity for HVAC purposes.

Table 5 Electricity consumption in harbour for the Tun island ferry and Eco-Island ferry

Electricity consumption	Tun island ferry	Eco-Island ferry
Electrical power consumption in harbour per year (HVAC etc.) [kWh]	65472	73600

The electricity price used is based on the current electricity price for the Tun island ferry, and is set to 0.16 euro per kWh.

4.4.2 Maintenance costs

The maintenance costs consist of costs for maintaining the machinery, the superstructure and the hull.

In the maintenance cost for the hull there is a large difference between the steel ferry and the composite ferry. The composite hull will have no corrosion, which is the main cause of the need for maintenance for steel hulls. The maintenance cost for steel hulls will increase rapidly during the last years of the lifetime of the ship, while for composite ships it is assumed that the cost will remain at the same level.

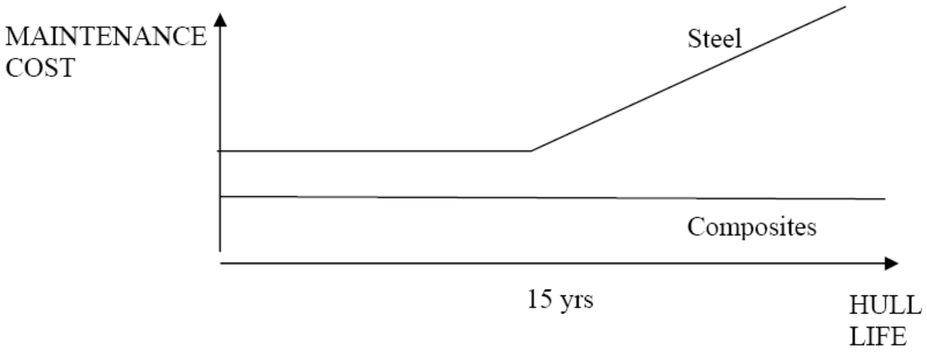

Figure 4 Illustration of maintenance costs over time

According to Kockums [9], the reduction in maintenance cost for the hull is 80% over a time period of 10 years, when comparing a composite hull to a steel hull. The reduction in maintenance cost for the hull will probably increase as the age of the ships increases. A similar development is assumed for the superstructure maintenance costs. However, the maintenance cost for the machinery will not decrease as much, even though the composite ferry will have smaller machinery and therefore probably somewhat lower costs. A reduction of 50% of the total maintenance cost (including hull, superstructure and machinery) is therefore assumed during the whole lifetime.

The maintenance cost is hard to estimate. In a market investigation [2] a survey was sent to ship operators, asking among many other things for their maintenance costs and their turnover. The average cost for maintenance is about 8.8 % of the turnover. The maintenance cost for the steel ferry is thus estimated as 8.8% of the turnover of the existing Tun island ferry. No increase in maintenance cost because of increasing age is assumed, since the average value used from the market investigation includes ships of different ages.

Table 6 Maintenance cost for the Tun island ferry and the Eco-Island ferry

	Tun island ferry	Eco-Island ferry
Maintenance cost [€/yr.]	71 000	35 000

As mentioned in Chapter 3.1, the cost for downtime is not included in the analysis.

4.4.3 Distribution between operation and maintenance costs

The distribution between the operation and maintenance costs during the 20 years of operation at current price is shown in Figure 5:

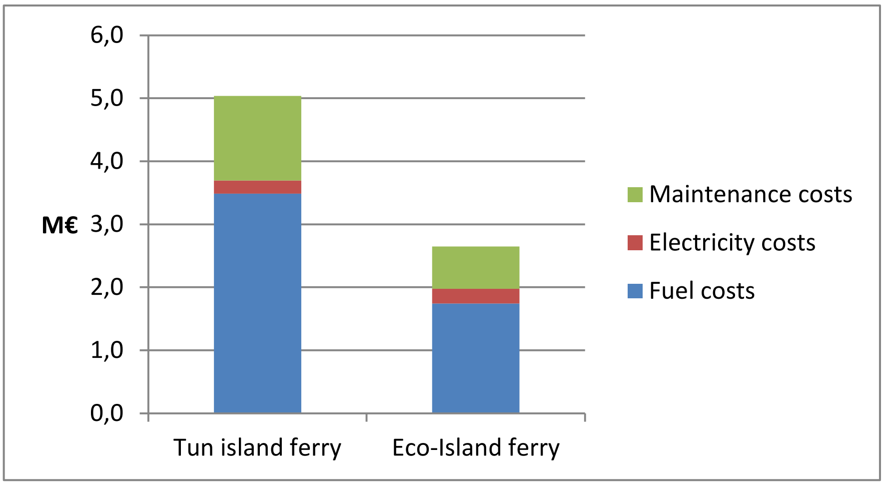

Figure 5 Operation and maintenance costs during 20 years, at current price

As seen in Figure 5, the fuel costs are the largest share of the operating and maintenance costs. The larger amount of electricity used by the Eco-Island ferry has a small impact on the total operating costs.

4.5 Rest value

The technical life time of the ferries is supposed to be more than 20 years in operation. The steel ferry is assumed to have a lifetime of about 30 years, and the lifetime of the composite ferry is estimated to about 40 years. This means that the ships will have a rest value after the 20 years of operation included in this analysis.

The rest value will depend on the market value of the ferry at that time. The market value will depend on if there is an interested buyer in need of a boat. Depending on whether there is an interested buyer, the market value could be high or practically zero. It is impossible to predict if there will be an interested buyer but to make a fair comparison between the ships the rest value is estimated to 30% of the production costs for both ships.

Table 7 Rest value after 20 years of operation for the Tun island ferry and the Eco-Island ferry

	Tun island ferry	Eco-Island ferry
Rest value [M€]	1.4	1.6

Another way of estimating the value at the end of the life cycle is by using the disposal cost. In this case, it is found more suitable to use the rest value approach. As mentioned above, the ferries are assumed to have a longer technical lifetime than 20 years, which means that the time span has to be extended if the disposal cost is to be used. To make it more complicated, the ships are not supposed to have the same life time. The composite ferry will have a longer technical life time than the steel ferry. But the steel ferry will generate an income when disposed, while it is possible that the disposal of the composite ferry will be an expense. Another way of estimating the rest value, which includes the disposal costs, is shown in the sensitivity analysis in section 6.4.

5 Results

Costs during the life cycle are presented both at current price and in present value. For the costs presented in present value, a break-even point is calculated. The results in this chapter are based on the assumptions stated in chapter 4.

5.1 Costs at current price

In this chapter, the costs are presented at current price. Figure 6 below shows the total life cycle cost for the two ferries at current price.

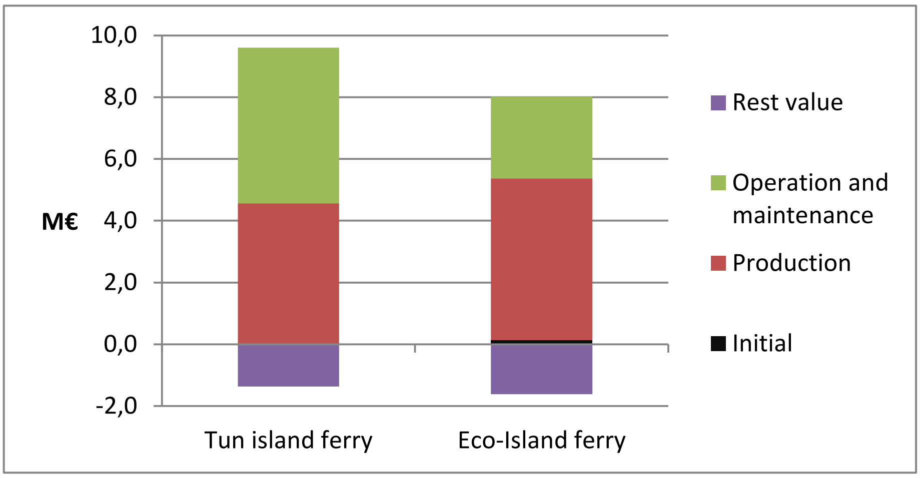

Figure 6 Contribution from different phases in the life cycle cost, presented at current price

For the Eco-Island ferry, the largest share of the costs at current price originates from the production phase, whereas the largest share for the Tun island ferry comes from operation and maintenance.

The Eco-Island ferry has the lowest total accumulated costs at current price.

5.2 Present value of future cost and break-even

In this chapter the present value is calculated as described in Chapter 3.2.

The accumulated costs for the two ferries during the whole life cycle are shown in the diagram below, expressed in present value. Notice the break-even point when the two lines cross.

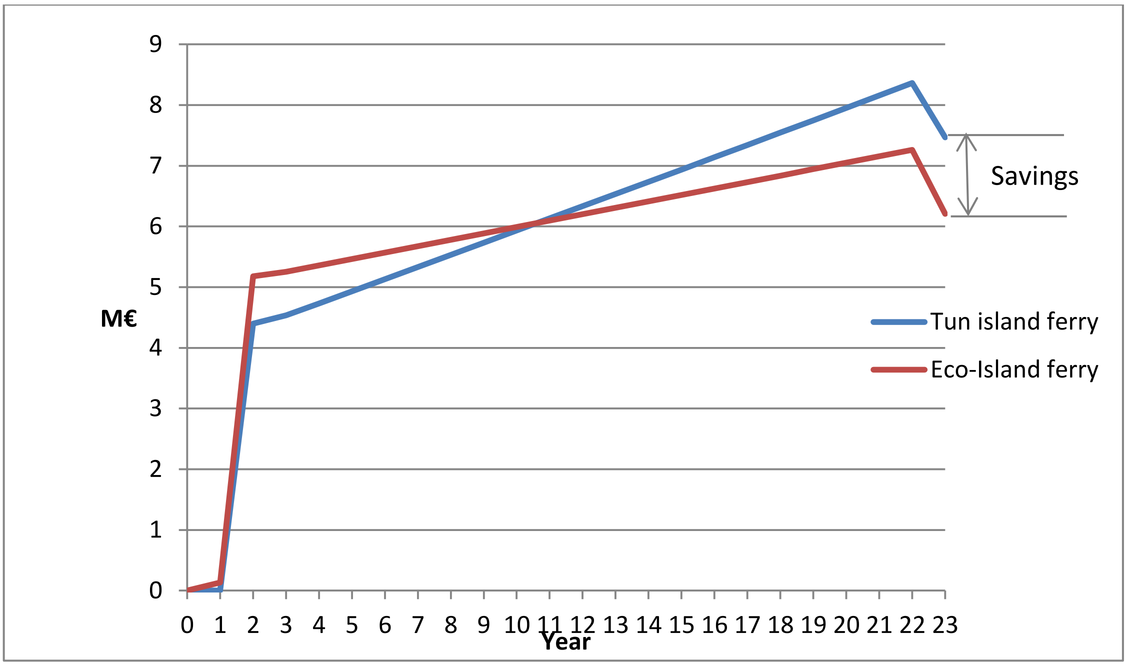

Figure 7 Accumulation of costs during the life cycle shown at present value, including initial costs, production costs, operation and maintenance cost and rest value (operation starts after 2 years)

It can be seen that the Tun island ferry option has the lowest accumulated costs in the beginning, because of the lower production cost. The break-even is after 10.6 years, whereof 8.6 are in operation. In total the Eco-Island ferry has the lowest accumulated costs after the total life cycle. The difference at the end of the life cycle in present value is M€ 1.3 in favour of the Eco-Island ferry. These results are referred to as the base case in the sensitivity analysis. It should be noted that the difference in costs between the ferries is of more interest than the absolute values of the costs, since costs that are assumed to be the same for both options are not included.

The distribution between the accumulated costs in present value is shown in Figure 8.

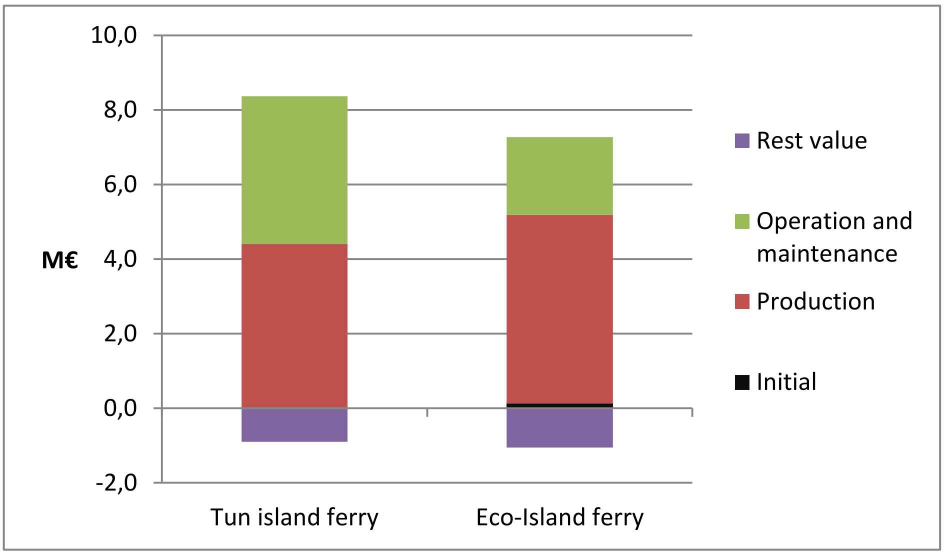

Figure 8 Contribution from different phases in the life cycle cost, presented at present value

Compared to the costs presented in current price, it can be seen that the share of the costs which occurs from the operation phase is decreased compared to the production costs, since they take place further in the future.

6 Sensitivity analysis

As seen in Figure 8, the main costs occur in the production phase and in the operation phase. The effect of different parameters for the operating phase has been investigated. The parameters found to be most important for the result are presented below. An analysis using a different approximation for the rest value is presented as well. In Appendix C, the effect of changing several parameters at once is investigated. Furthermore, the effect of the interest rate has been investigated and the results are presented in Appendix B.

For all cases presented in this chapter it is true that the Tun island ferry has the lowest accumulated costs during the first years, and that the Eco-Island ferry has the lowest accumulated cost after the complete life cycle. The break-even time and the total difference after the whole life cycle will be different depending on the variation in parameters tried.

6.1 Fuel price

The future fuel price is hard to predict. The general opinion is that the fuel price will increase, but the question is to what extent. In the base case of this study, a yearly increase with 3% in addition to inflation is used, based on the development of the fuel price the last 20 years. However, the development may be another. Due to oil scarceness and increasing energy demand of the world, together with plausible new taxes, the fuel price might rise more. In Figure 9, the result of the life cycle cost analysis is shown if the fuel price instead would increase with 5% annually.

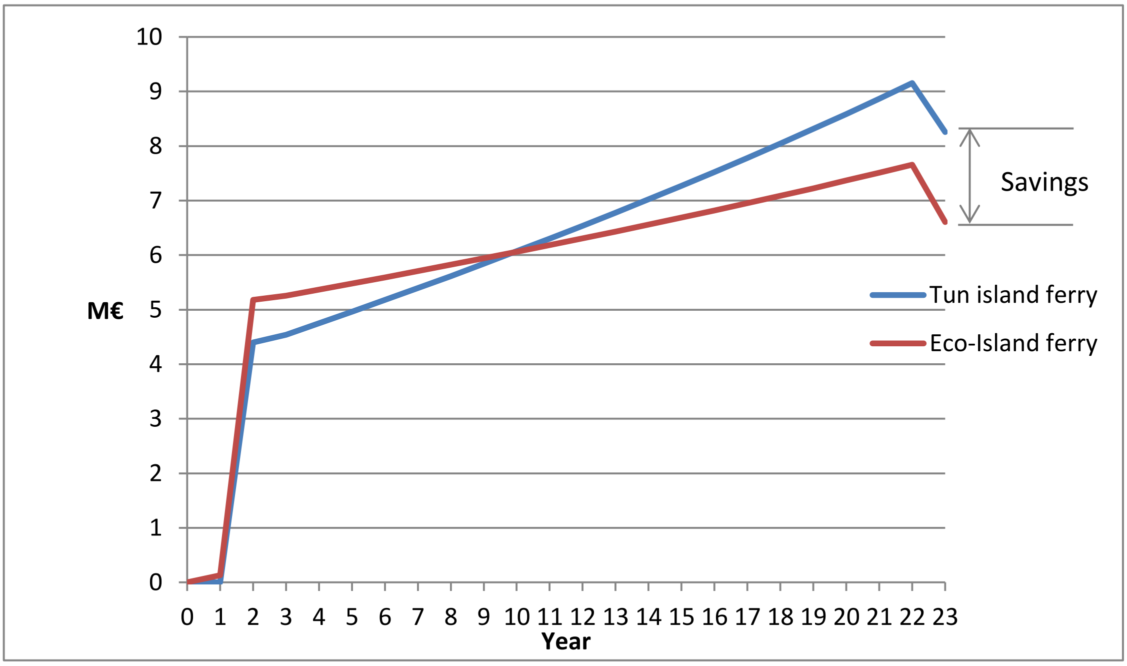

Figure 9 Accumulation of costs at present value with an annual increase in fuel price with 5%

As seen in Figure 9, the higher fuel price shortens the time until break-even. Compared to the base case, the time period before break-even is decreased by 0.7 years.

The results for some other possible developments of the fuel price are found in Table 8.

Table 8 Variation of fuel price

Yearly increase in fuel price:	Break even [yrs. from project start]	Break even [yrs. in operation]	Total difference after complete life cycle expressed in present value [M€]
0%	12.0	10.0	0.8
3% (base case)	10.6	8.6	1.3
5%	9.9	7.9	1.7
10%	8.5	6.5	3.3

In general, a high fuel price favours the Eco-Island ferry, since it has the lowest fuel consumption.

6.2 Operating hours

Today, the existing Tun island ferry travels approximately two return trips per day, leading to a daily operating time of 4 hours. This might change in the future, and is found to have a large impact on the result of the analysis. In Figure 10 below, the result for the life cycle analysis is shown if the number of trips were to be increased to three trips a day.

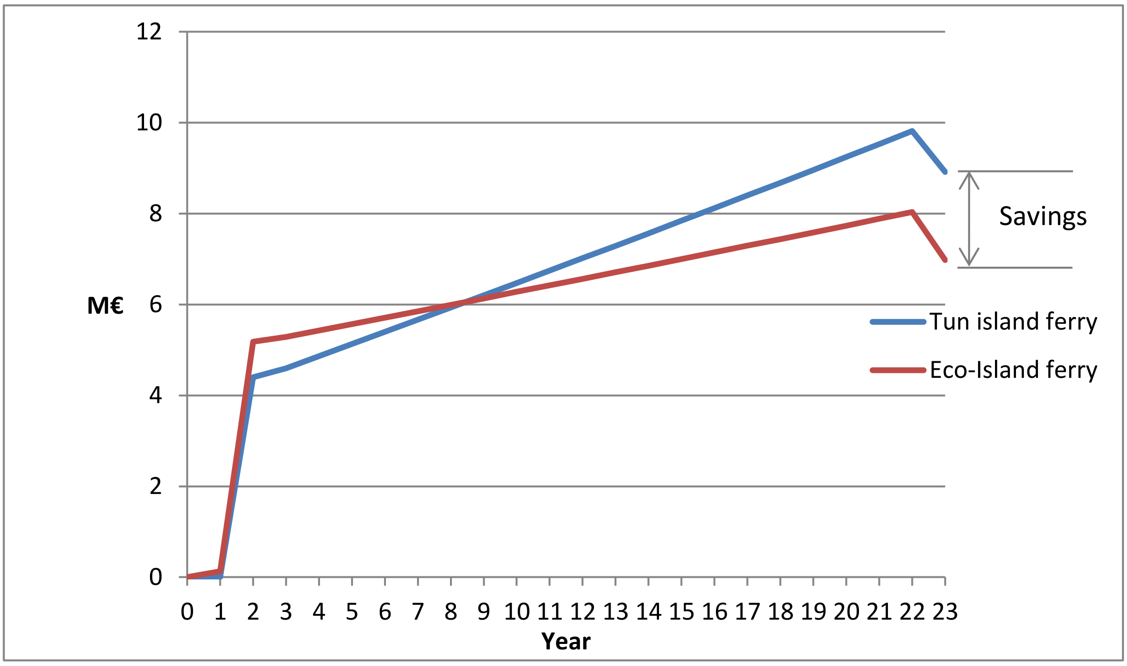

Figure 10 Accumulation of costs at present value with 3 return trips per day

When comparing Figure 10 to the base case shown in Figure 7, it can be seen that the break-even time decreases with 2 years if the number of daily tours is increased to three instead of two.

But the operating time might also be decreased. In Table 9, the results for different cases are showed.

Table 9 Variation of operating time

Trips/day (One trip takes 2 hours)	Break even [yrs. from project start]	Break even [yrs. in operation]	Total difference after complete life cycle expressed in present value [M€]
1	14.1	12.1	0.7
2 (base case)	10.6	8.6	1.3
3	8.5	6.5	1.9
4	7.3	5.3	2.6

As for the fuel price, a high operating time favours the Eco-Island ferry, since it has the lowest running costs. When the number of trips increases, the maintenance cost could be expected to increase as well. This is not included in the analysis. The decreased needs for fuel and electricity in harbour are neither included.

6.3 Maintenance costs

The maintenance costs are hard to estimate, because of lack of data. Therefore it is included in the sensitivity analysis, and the results are shown in Table 10.

Table 10 Variation of maintenance costs

Maintenance costs for the Tun island ferry as part of turnover	Break even [yrs. from project start]	Break even [yrs. in operation]	Total difference after complete life cycle expressed in present value [M€]
5%	11.9	9.9	1.0
8.8% (base case)	10.6	8.6	1.3
15%	9.2	7.2	1.6

Since the mean value in the survey was 8.8 % of turnover, it is reasonable that the real costs will be somewhere between 5% and 15%. It can be seen that a lower costs for maintenance favours the Tun island ferry, since the savings for the Eco-Island ferry are less.

6.4 Rest value

In the base case, the rest value was approximated as 30% of the production cost. Another way of approximating the rest value is by using the disposal costs. The steel ferry is supposed to have a technical life-time of 30 years and then generate an income of € 33 500 when disposed. The composite ferry on the other hand is believed to have a technical lifetime of 40 years, and to have a disposal cost of € -9 600.

The value after 20 years could be calculated using linear interpolation between the start value (the production cost) and the disposal cost after the technical life-time.

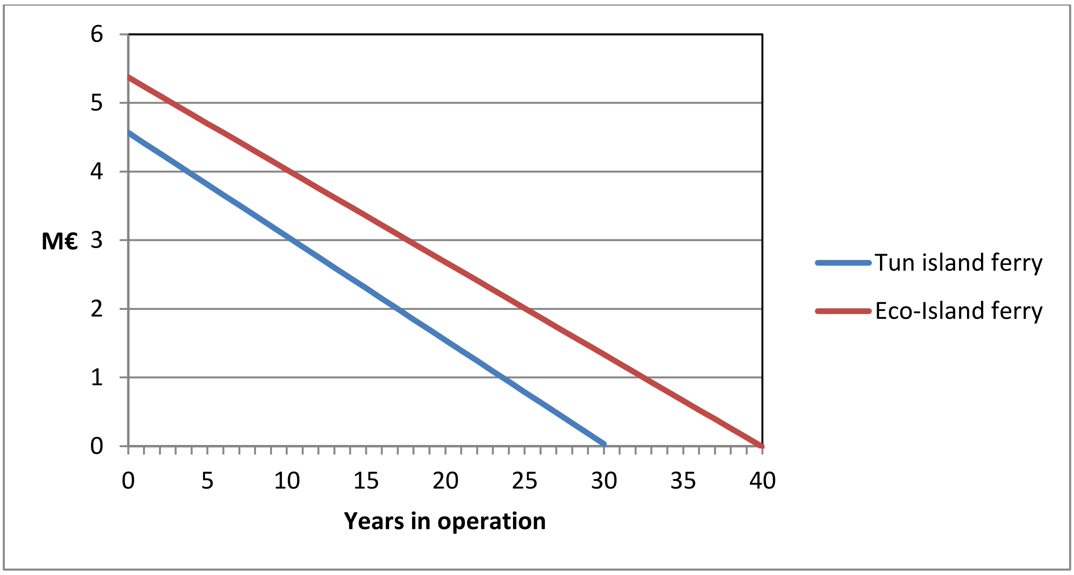

Figure 11 Approximated value of the ferries during their operational life-time, shown at current price

Figure 11 shows the approximated value of the ferries during their operational life-time, where year 0 is when they are first taken into operation. From this, the rest value for the ferries after 20 years of operation are as follows:

Table 11 Rest value at current price after 20 years of operation for the Tun island ferry and the Eco-Island ferry, approximated using disposal costs

	Tun island ferry	Eco-Island ferry
Rest value [M€]	1,5	2,7

The rest value used in the base case, using the approach of 30% described in section 4.5, was 1.4 M€ for the Tun island ferry and 1.6 M€ for the Eco-Island ferry. It can be seen that the rest value for the Tun island ferry is similar to the rest value obtained when using the approach in section 4.5, whereas the rest value for the Eco-Island ferry is significantly higher. The time until break-even is not affected by the rest value. However, the total difference after the complete life cycle for the ferries will be larger.

Table 12 Results from the life cycle analysis when a rest value approach based on disposal cost is used

	Break even [yrs. from project start]	Break even [yrs. in operation]	Total difference after complete life cycle expressed in present value [M€]
Rest value approximated from disposal costs	10.6	8.6	1.8
Rest value approximated as 30% of production cost (base case)	10.6	8.6	1.3

Because of the higher rest value for the Eco-Island ferry compared to the base case, the total difference between the ferries after the complete life cycle is larger, favouring the Eco-Island ferry alternative.

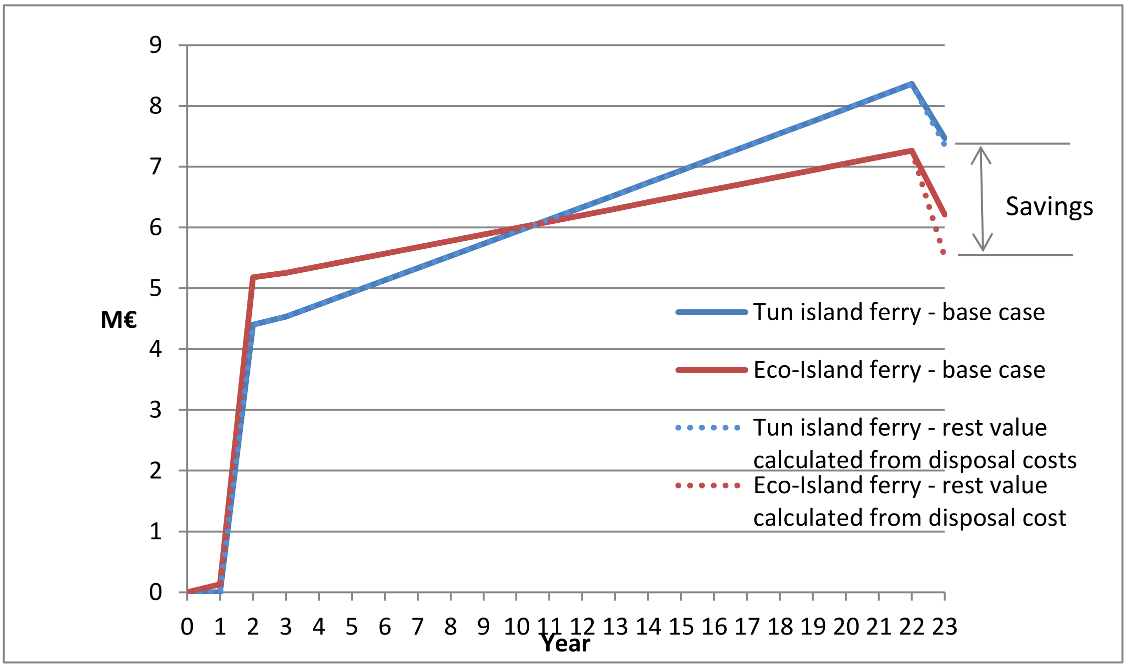

Figure 12 Accumulation of costs at present value during the life-cycle, comparing the two different rest value approaches.

7 Discussion

The Tun Island Ferry is the cheapest option at a short perspective. However, after a number of years the accumulated costs of the Eco-Island ferry are equal and after the whole life cycle the lightweight ship was found to have the lowest total cost. The more the ferry is used, and the higher the fuel price, the more favourable becomes the Eco-Island ferry.

It could be seen that the largest share of costs at present value for the Eco-Island ferry originates from the production phase, whereas it was more evenly distributed between the production phase and the operational phase for the Tun island ferry. If the operating time were to increase, the share originating from the operational phase would increase as well.

The time until break-even for the base case investigated is slightly less than 9 years in operation. As seen in the sensitivity analysis, the time for break-even differs depending on which future scenario used, both for the future fuel price and the operating time.

There are uncertainties about the future fuel price and there is also a chance that ships will be included in the EU emission trading scheme, resulting in an additional cost for emitting carbon dioxide. This will favour the Eco-Island ferry because of its lower fuel consumption and consequently lower emissions.

8 References

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Appendices

A. Results from the LCCA
B. Variation of interest rate
C. Sensitivity analysis, fuel price and operating hours

Appendix A

Results from the LCCA

Table 13 Detailed results from the LCCA

			Tun island ferry			Eco-Island ferry		
			€		M€	€		M€
	Cost element	**Year**	Current Price	Present value	Total [M€]	Current Price	Present value	Total [M€]
Initial	Initial	1	0	0	0,0	134306	131852	0,1
Production	Production	2	4566390	4401066	4,4	5237918	5048281	5,2
Operation and maintenance	Operation	3	140107	132567	4,5	76494	72378	5,3
	Operation and maintenance	4	214750	199482	4,7	113814	105722	5,4
	Operation and maintenance	5	218758	199492	4,9	115817	105617	5,5
	Operation and maintenance	6	222887	199544	5,1	117879	105534	5,6
	Operation and maintenance	7	227139	199636	5,3	120004	105473	5,7
	Operation and maintenance	8	231518	199767	5,5	122192	105434	5,8
	Operation and maintenance	9	236029	199939	5,7	124446	105417	5,9
	Operation and maintenance	10	240676	200150	5,9	126767	105422	6,0
	Operation and maintenance	11	245462	200401	6,1	129158	105448	6,1
	Operation and maintenance	12	250391	200691	6,3	131621	105496	6,2
	Operation and maintenance	13	255468	201019	6,5	134158	105564	6,3
	Operation and maintenance	14	260698	201387	6,7	136771	105654	6,4
	Operation and maintenance	15	266084	201793	6,9	139462	105765	6,5
	Operation and maintenance	16	271632	202237	7,1	142234	105896	6,6
	Operation and maintenance	17	277347	202719	7,3	145089	106049	6,7
	Operation and maintenance	18	283233	203239	7,5	148030	106221	6,8
	Operation and maintenance	19	289295	203797	7,7	151059	106415	6,9
	Operation and maintenance	20	295540	204392	8,0	154178	106628	7,1
	Operation and maintenance	21	301971	205025	8,2	157392	106862	7,2
	Operation and maintenance	22	308596	205695	8,4	160702	107116	7,3
Rest value	Rest value	23	-1369917	-896437	7,5	-1611667	-1054631	6,2
				Total	**7,47**		**Total**	**6,21**

Variation of interest rate

In this appendix, changes in the interest rate are investigated. The results are found in Table 14.

For all cases presented it is true that the Tun island ferry has the lowest accumulated costs during the first years, and that the Eco-Island ferry has the lowest accumulated cost after the complete life cycle.

Table 14 Variation of interest rate

Interest rate	Break even [yrs. from project start]	Break even [yrs. in operation]	Total difference after complete life cycle expressed in present value [M€]
2%	9.9	7.9	1.9
3%	10.2	8.2	1.5
5%	11.1	9.1	1.0

Sensitivity analysis, fuel price and operating hours

In this appendix, the effect of changing both operating time and fuel price is shown. Case 1 shows the scenario which favours the Tun island ferry the most and case 12 shows the scenario which favours the Eco-Island ferry the most.

For all cases presented it is true that the Tun island ferry has the lowest accumulated costs during the first years, and that the Eco-Island ferry has the lowest accumulated cost after the complete life cycle. When the number of trips increases, the maintenance cost could be expected to increase as well. This is not included in the analysis. The decreased needs for fuel and electricity in harbour are neither included.

Table 15 Variation of operating hours and fuel price

Case number		Break even [yrs. from project start]	Break even [yrs. in operation]	Total difference after complete life cycle expressed in present value [M€]
1	Trips/day: 1 Yearly increase in fuel price: 0%	16.1	14.1	0.4
2	Trips/day: 1 Yearly increase in fuel price: 5%	13.1	11.1	0.9
3	Trips/day: 1 Yearly increase in fuel price: 10%	11.0	9.0	1.9
4	Trips/day: 2 Yearly increase in fuel price: 0%	12.0	10.0	0.8
5	Trips/day: 2 Yearly increase in fuel price: 5%	9.9	7.9	1.7
6	Trips/day: 2 Yearly increase in fuel price: 10%	8.5	6.5	3.3
7	Trips/day: 3 Yearly increase in fuel price: 0%	9.4	7.4	1.3
8	Trips/day: 3 Yearly increase in fuel price: 5%	8.0	6.0	2.5
9	Trips/day: 3 Yearly increase in fuel price: 10%	7.0	5.0	5.0

Appendix C

10	Trips/day: 4 Yearly increase in fuel price: 0%	8.0	6.0	1.7
11	Trips/day: 4 Yearly increase in fuel price: 5%	6.9	4.9	3.3
12	Trips/day: 4 Yearly increase in fuel price: 10%	6.1	4.1	6.6