Activity-based life-cycle costing

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Abstract
The purpose of this paper is to present a new method for life-cycle costing (LCC) called activity-based LCC by employing the comprehensive activity-based life-cycle assessment method. A real-life case study of a platform supply vessel operating in the North Sea is utilized to present the method, illustrate an implementation, including results, and discuss the benefits. Furthermore, due to the inherent uncertainty in LCC, handling of uncertainty is emphasized. A crucial side-effect of handling uncertainty by employing Monte Carlo simulations – as activity-based LCA prescribes – is the greatly enhanced tracing of critical success factors. Such tracing enables the shipowners to increase long-term profitability by focusing on what is critical to their success. Also, a design option of using heavy fuel oil versus marine gas oil is investigated.

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1. Frame of reference

As organizations becomes increasingly aware of both environmental costs and customer service costs, life-cycle costs will become more and more important to assess, predict and trace. This growing awareness gave room for a project between Møre Research and Farstad Shipping ASA described fully in Fet *et al.* (1996). In this project the following economical and environmental aspects were analyzed:
- the vessel "as is", and
- the choice of propulsion machinery and belonging support systems.

Only the costing part is discussed here, and it is handled by using the activity-based life-cycle assessment (LCA) method described fully in Emblemsvåg, (1999) and Emblemsvåg and Bras (2000), which can be used to develop several types of models, such as:
1 Complete activity-based LCA systems that handle both environmental impact, quality, time and costs in an integrated framework.
2 Activity-based LCA systems that only capture environmental issues.
3 Models for financial analysis, uncertainty analysis and critical assumption planning (CAP).
4 Straightforward activity-based costing (ABC) models as shown in Emblemsvåg and Bras (1994).

Note that some input information in the model is confidential and the results are somewhat distorted on purpose. The method and the associated model are therefore the focus of this paper – not the results *per se.*

Before continuing, the content of this paper must be anchored. Specifically, some aspects of activity-based LCA are discussed and contrasted to other methods, which is done next. In Section 3 the development of the LCC model is presented followed by the results and the associated discussion in Section 4. The paper is concluded in Section 5.

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2. Some issues regarding activity-based LCA

Activity-based LCA is a life-cycle assessment/ analysis method with similar scope as the well known ISO 14000 LCA, but it has several major advantages over the ISO approach explained extensively in Emblemsvåg, (1999) and Emblemsvåg and Bras (2000) such as:
1 Activity-based LCA utilizes an environmental impact indicator that always yields comparable results whereas the ISO 14000 LCA cannot produce comparable results and hence inhibit rank prioritization, see e.g. Hanssen (1998).
2 Activity-based LCA is based on the highly effective ABC method which, in conjunction with total quality management (TQM), becomes even more effective, and can therefore directly harvest all the advantages of the so called ABC-TQM continuum. ISO 14000 LCA, in contrast, only draws upon TQM and misses the vital link to over 200 years of cost management experience.
3 Activity-based LCA is an integrated framework where cost and environmental issues are equally attended. ISO 14000 LCA, in contrast, ignores costs almost completely. Since LCC is the topic here, a brief review of ISO 14000 w.r.t. LCC is presented later.
4 Activity-based LCA performs assessments of all products and the entire organization in the same model at the same time whereas in ISO 14000 LCA tends to focus on product by product, see e.g. ISO/TC 207/SC 5 (1996). This can, as shown in the Interface case study – the worlds leading carpet tile manufacturer – see e.g. Emblemsvåg and Bras (2000), lead to outright wrong conclusions due to, e.g. economies-of-scale effects.
5 Activity-based LCA is the only LCA method that can credibly handle overhead

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resources, i.e. according to modern cost management principles. This is also a logic extension of Point 4.

Since ABC is crucial to activity-based LCA, some explanation of ABC is pertinent. ABC is a full-absorption costing method that gains more and more ground on conventional [1] methods, see e.g. Brinker (1994), due to both more correct cost assessments and superb tracing of the costs. Conventional costing systems, on the other hand, cannot trace – overhead costs are simply distributed as butter on bread (Hardy and Hubbard, 1992) without estimating the effect of all the complexities (see Eiler and Ball, 1997). The tracing capability is enhanced by the usage of uncertainty and sensitivity analysis in activity-based LCA. Compared to the conventional costing systems, ABC differs in two major points (Cooper, 1990a):

1. In an ABC system it is assumed that cost objects (products, services and so forth) consume activities, while a conventional system assumes that cost objects consume resources. There are several implications of this difference, but the most important is that ABC acknowledges that one cannot manage costs, one can only manage what is being done, i.e. activities.
2. An ABC system utilizes drivers on several levels (unit-, batch-, product- and factory level), while a conventional system uses only unit-level characterizations called allocation bases, which roughly speaking is an arbitrary, unit-level driver. Hence, ABC is much more accurate. In fact, O'Guin (1990) reports that product cost estimates from a conventional costing system can differ by several hundred percent compared to an ABC system.

In-depth discussions of ABC can be found in Cooper (1990a), Brinker (1994) and Edwards (1998). A motivating example of ABC used in an environmental context is found in Brooks *et al.* (1993).

Due to the inherent uncertainty in design, management and forecasting in particular, the uncertainty must be included in LCC. In activity-based LCA, the uncertainty is handled by modeling the uncertainty as fuzzy numbers and fuzzy intervals and solving the model numerically by employing Monte Carlo simulations, and this approach has two great advantages:

1. The usage of fuzzy numbers and intervals allows complete freedom in modeling and analyzing the uncertainty. This is impossible in ordinary statistics and the like.
2. Tracing of critical success factors is enhanced by the statistical nature of Monte Carlo simulations.

The Monte Carlo simulation technique is employed to find numerically how the assumptions (where the fuzzy numbers and intervals are modeled) affect the forecasts. An assumption is a source variable (any product or process parameter), whose variability (modeled as uncertainty) inflicts changes in the forecast(s). A forecast can therefore be viewed as a response variable (any cost, revenue and/or profitability is the model you want to investigate) whose response in measured statistically. The response must be measured statistically because a Monte Carlo simulation is a numerical approximation method. The number of trials in the simulation is therefore important since the reliability of the model can be affected due to random effects (Emblemsvåg, 1999).

Most LCC methods in the literature can be characterized by: the methods are not costing methods but cash flow analyses, see e.g. Hanssen (1998); and the methods use assessments and do not assess *per se*; they are Life-Cycle Accounting methods, see e.g. (Wood, 1998). The problem with cash flows analyses is that they represent spending (positive and negative) flows that investigate the capacity provided to do a job. In contrast, a costing model keeps track of resource consumption and the demand for jobs to be done. It is the resource consumption perspective that counts, (see Cooper, 1990b), because management must match capacity to demand and not the other way around. Hence, cash flow analyses are totally inappropriate for costing purposes.

Please note that the term LCC has been used for years in marketing, see e.g. Allvine (1996), but for a completely different life-cycle (launch – growth – maturity – decline) and for cash flow purposes.

Other aspects pertinent to LCC and the overall framework will be presented in the next sections as the case study proceeds. For further details please see Emblemsvåg (1999), Emblemsvåg and Bras (2000).

3. Developing the activity-based LCC model

When developing the activity-based LCC model the activity-based LCA method is employed directly except that only costs are included and only the operational phase of the vessel is handled just as in the project. We start by defining the problem as any other method.

3.1 Problem statement

Operating a platform supply vessel (PSV) is not easy because competition is very stiff, and the longer the contracts, the harder the competition because the revenues of

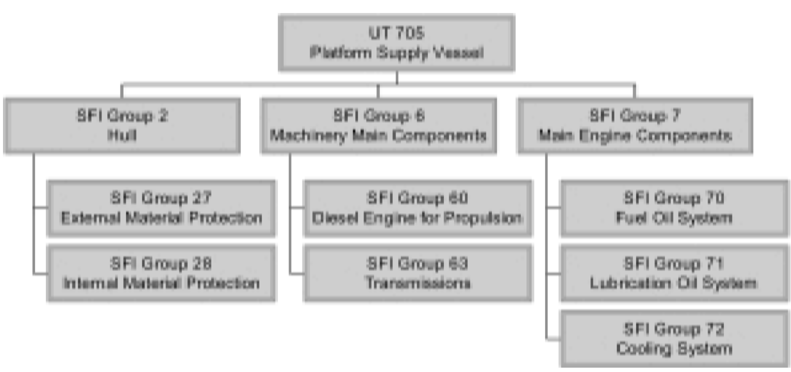
spot-market contracts are associated with large uncertainties. Even with stable revenues, significant problems related to the maintenance, service and repair activities (see Glossary) exist, but most importantly:
- How can the amount of off-hire be reduced?
- How can the life-span costs be reduced?
- How can profitable contracts be acquired?

Depending on the contract, off-hire will occur in different situations. For Farstad Shipping the situation is:
- Planned service on dock is not considered off-hire.
- Unplanned repairs are considered off-hire.
- The shipowners are given one lay day per month, but the maximum annual aggregated number of lay days is set to be six lay days per year. Hence, annual service time that exceeds six days is considered off-hire.

The life-span costs (the LCC of the operational phase) have nothing to do with the contract except that the costs must be predicted up to five years ahead before negotiating with an oil company – a charterer – or new ships are designed. In the model the life-span costs are assessed, traced and predicted, and a design scenario is investigated – Design scenario A: assess the costs and benefits of using heavy fuel oil (HFO) called IF 40 instead of the current fuel, marine gas oil (MGO). The tracing of significant cost contributors – critical success factors – enables improvement through (re)design. Also, the critical success factors can be used to simply tell the shipowners where to focus their attention and data collection for further analysis.

Because a UT 705 PSV is a large and complex system the analysis was constrained – in agreement with Farstad Shipping – to the most significant subsystems of the ship presented in Figure 1. The subsystems are grouped according to the SFI grouping system.

Figure 1
The seven main subsystems to be studied



In the following section, an activity-based LCC model that allows detailed cost and revenue analysis according to the previously mentioned problem statement will be outlined.

3.2 The steps of implementing the activity-based life-span costing model

The method used to develop the costing model is found in e.g. Emblemsvåg (1999), Emblemsvåg and Bras (2000), and in Figure 2 a short description of the method is given. Each step is followed in turn except steps 6, 7 and 8 which are iterative steps. Step 5 is also omitted since the model works according to ABC principles and the Monte Carlo simulations are straightforward.

3.2.1 Step 1 – create an activity hierarchy and network

Step 1 starts by forming an activity hierarchy. When the hierarchy is made, an activity network is formed. The circular nodes in the network are activities, while the diamond shaped nodes are design decision nodes. The letter in the decision nodes represents the different design scenarios. In Table I the activity hierarchy for the model is presented. The activities are chosen to both capture costs well.

As depicted in Table I, four different levels of activity are present. For example, activity A3 (“Repair”) consists of three level 2 activities – “Dock ship”, “Repair machinery” and “Repair propellers”. The three level 2 “Repair” activities are far from the only unwanted incidents that can happen, but based on historical data these unwanted incidents were chosen due to their relatively frequent occurrence compared to other incidents like fire, collision and war. The system boundary of the project also limits which incidents to consider. In the activity network we use the lowest level activities from the activity hierarchy in Table I (the shaded cells). In Figure 3 the resulting activity network is presented.

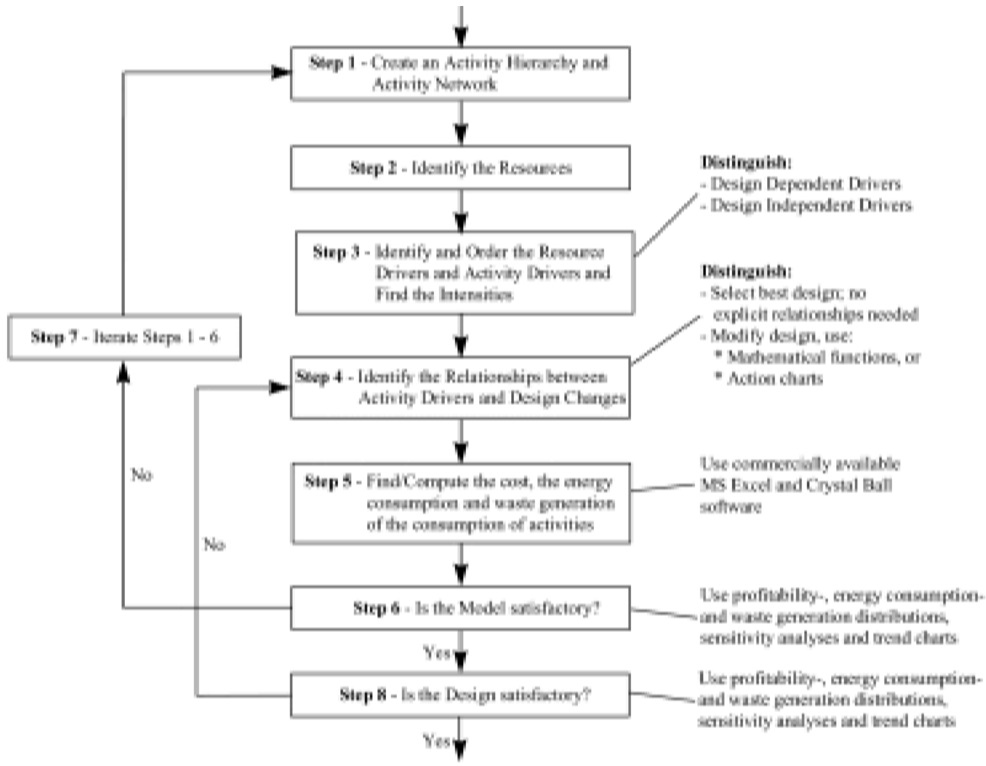
3.2.2 Step 2 – identify the resources

Due to confidentiality only selected resources can be presented, see Table II. Revenues are also omitted since they indicate the bargaining power of Farstad Shipping. Please note that in 1995 US$1 = Norwegian Krona 6,50.

3.2.3 Step 3 – identify and order all the resource drivers and activity drivers and find the intensities

The activity-based LCC model is extensive. Hence, presenting all the drivers and consumption intensities (when known) is unfeasible. The most important resource drivers are:

Figure 2
Implementing activity-based LCA models for design and management



- *Direct labor*. This resource driver is mostly used to capture the maintenance and service activities performed by the crew and the workers at shipyards. However, for shipyards it is necessary to split "direct labor" into four new resource drivers: ordinary direct labor; 50 per cent overtime direct labor; 100 per cent overtime direct labor and shift direct labor. The maintenance related "direct labor" resource driver is not believed to affect the choice between the different fuel type for the machinery. In Figure 4 the A1416 Job 0.61 resource driver for component number 601.1-2.01 is modeled. The unit is [h], i.e. hours/year.
- *Number of components*. This resource driver is normally employed to capture the cost of replacing components in the machinery, and is highly affected by different fuel types for the machinery. It is therefore a design dependent driver.
- *Running hours*. This resource driver is used to determine the use pattern of the vessel, and it plays a key role (along with the "days in dock" resource driver) in determining when the vessel is off-hire. Furthermore, "running hours" is the resource driver the overhead is distributed by, but it is believed that it will not be affected significantly by any proposed design changes.
- *Fuel consumption*. This resource driver simply keeps track of the fuel costs for the vessel, and is highly affected by different fuel types and is consequently a design dependent driver.

Please note that since there is only one assessment object in the model activity drivers are not needed.

3.2.4 Step 4 – identify the relationships between activity drivers and design changes

Since there is only one assessment object in this model, the resource drivers will capture the design changes. Due to the fact that the consumption of activities depends on a variety of resource drivers, it is convenient to use historical data when available as a basis from which the relationships can be determined. This is unfortunately associated with more uncertainty than the usage of pure mathematical equations. However, it is the most feasible and probably the most reliable approach, because the variety of known and maybe unknown resource drivers is hard to model realistically as a set of equations.

The historical data are obtained by asking the crew on FAR Scandia, Bjarne Nygaaren (Farstad Shipping ASA, Ålesund) and

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Table I
Life-span activity hierarchy for the UT 705 platform supply vessel

Activity level 1		Activity level 2		Activity level 3		Activity level 4	
Use	**A1**	Operate ship	A11	Load ship	A111		
				Be in service	A112		
				Stand by	A113		
				Service platform	A114		
				Be out of service	A115		
		Entering harbor	A12				
		Maintain tanks	A13	Wash	A131		
				Test	A132		
				Check	A133		
		Maintain machinery	A14	Maintain SFI group 6	A141	Check	A1411
						Test	A1412
						Lubricate	A1413
						Get fluid sample	A1414
						Survey/control	A1415
						Overhaul	A1416
						Honing	A1417
						Replace comp.	A1418
				Maintian SFI group 7	A142	Check	A1421
						Test	A1422
						Replace components	A1423
						Survey/control	A1424
						Lubricate	A1425
		Certify class	A15				
Service		Dock ship	A21				
on dock		Service hull	A2	Sand-blast hull	A221		
				Paint hull	A222		
				Clean hull	A223		
		Service machinery	A23	Check	A231		
				Change oil	A232		
				Service cooling system	A233		
		Change anodes	A24				
		Service tanks	A25	Sand-blast tanks	A251		
				Paint tanks	A252		
				Clean tanks	A253		
Repair	**A3**	Dock Ship	A31				
		Repair machinery	A32				
		Repair propellers	A33				

Figure 3
Life-span activity network (icons as in Greenwood and Reeve (1992))

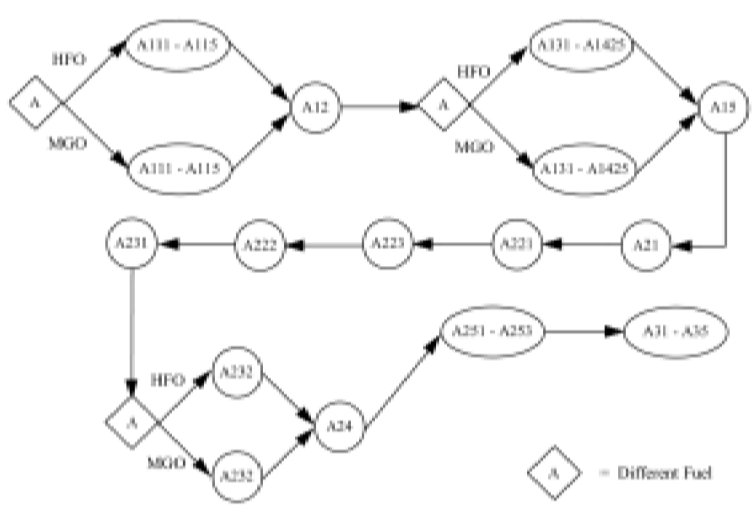


Table II
Identified resource elements

Resource	Costs (NOK/year)
Various types of insurance	620,000
Crew costs	6,697,600
Fuel costs (MGO)	3,774,000
Classification costs (annual average)	71,392
Harbor fees per entry	1,400

Figure 4
Modelling the A1416 job 0.61 resource driver for component No. 601.1-2.01

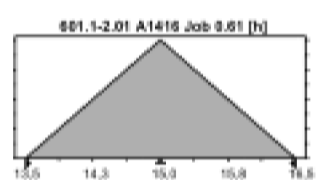


Table III
Typical FAR Scandia mission in 1995

Operation mode	Run hrs	% run hrs	Speed (nm/h)	Nominal fuel consumption (1,000kg/day)
In port	9.3		0.0	1.0
Stand by	0.0	0.0	0.0	4.0
Economic speed	2.1	5.4	10.0	14.3
Full speed	15.3	39.3	14.0	21.4
Service platform	21.5	55.3	0.0	4.8

Figure 5
Year 7 maintenance cost probability distribution using MGO fuel

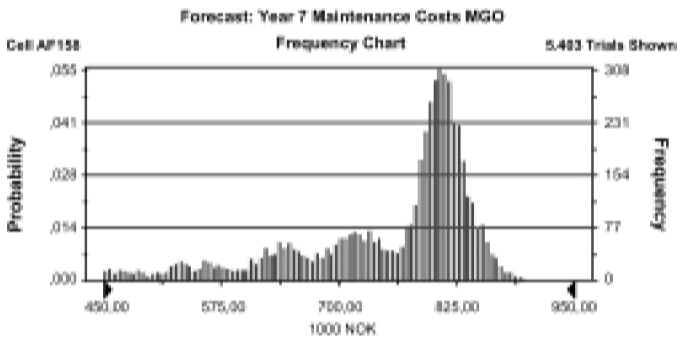


Figure 6
Year 7 maintenance cost sensitivity chart using MGO fuel

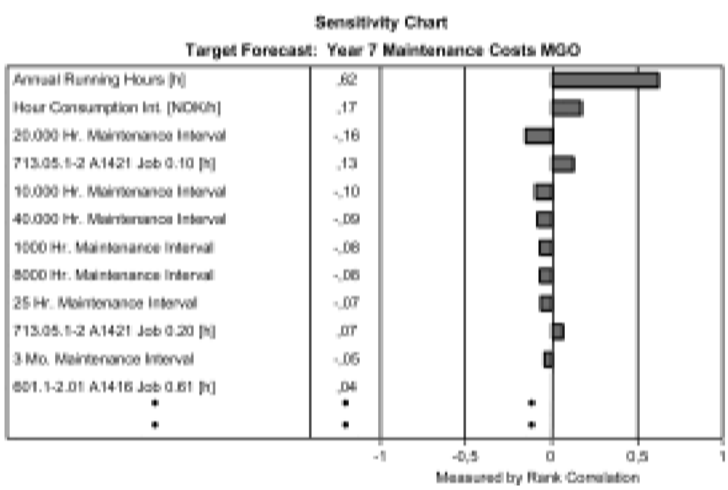
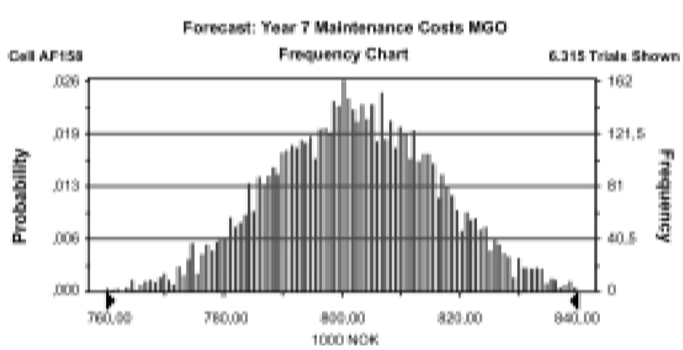


Figure 7
Year 7 maintenance cost probability distribution using MGO fuel



Jim Watt (Farstad Shipping Ltd, Aberdeen) to fill out some forms, and by using up to four-year old invoices from different shipyards. Some data were also from FAR Server and FAR Service.

In Table III the historical data obtained from FAR Scandia are presented. These historical data are used to quantify a cost driver – fuel consumption, in this case. Furthermore, the "% Run. hrs" is used to compute the "Run. hrs" cost driver, which captures the annual consumption of overhead resources. Please note that the "In port" operation mode is not included in the "% Run. hrs." since being in port is a state of no running.

3.2.5 Step 5 – find/compute the cost, energy consumption and waste generation of the cosumption of activities

There are two types of assumptions – user defined and user predefined. The user defined assumptions are modeled in the assumptions and can be changed whenever the user wants to. In this model there are many[2] user defined assumptions and only a small sample is presented (see Figure 4 and Table III).

The user predefined assumptions are assumptions that are made by the designer to simplify the modeling based on the user preferences and budget. These assumptions are therefore embodied in the framework of the model. In this model there are only a few of these predefined assumptions:

- The historical data are used as a good guideline for the future development. That is; we assume the future will proceed similarly as the past, which is common in all forecasting (Allvine, 1996).
- Real revenues and costs are assumed constant.
- The maintenance program for the vessels is followed accurately so that the jobs in the maintenance program are done as listed. The model, however, allows some variability (±10 per cent).
- The technical condition of machinery and hull remain constant as long as maintenance and service programs are followed. Thus, costs due to aging will not exist. Since only the first ten years of the life-span were considered, this assumption has very little influence on the results. For vessels older than 20 years the situation may be significantly different.

With these assumptions and design scenario A embodied in the model, the Monte Carlo simulations took place using Crystal Ball®, which adds into MS Excel®. The model is run 10,000 trials to get fairly accurate results.

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4 The results

The results and the discussions are divided into four main parts:

1. Using the results to check the model.
2. Using trend charts to predict and trace future costs and revenues.
3. Identifying the critical success factors for the shipowner.
4. Investigating design scenario A

4.1 Checking the model

To check the model the distribution of uncertainty in Figure 5 is investigated. Clearly, the amount of uncertainty is distributed very unequally. This is a problem in the general case; the forecast distributions are abnormal (bell shaped is normal).

Figure 8
Profitability for the vessel the first ten years. The units are 1,000 NOK

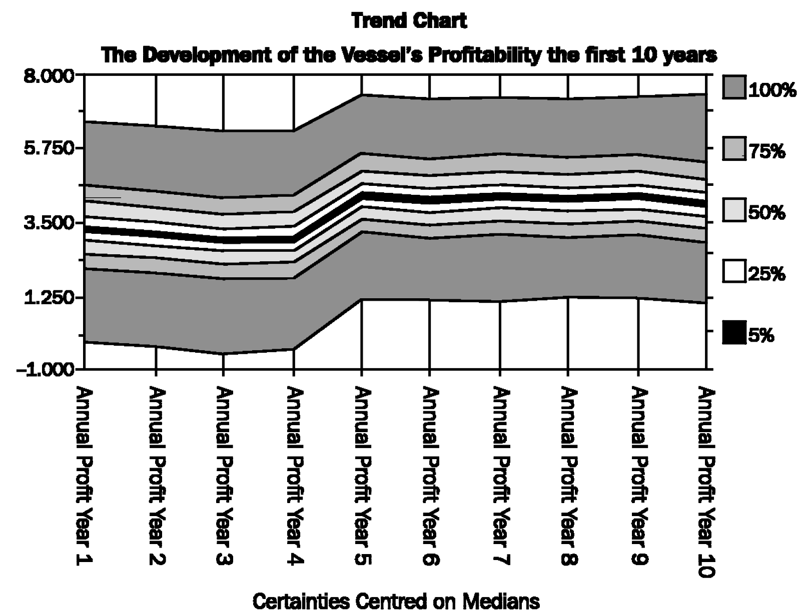
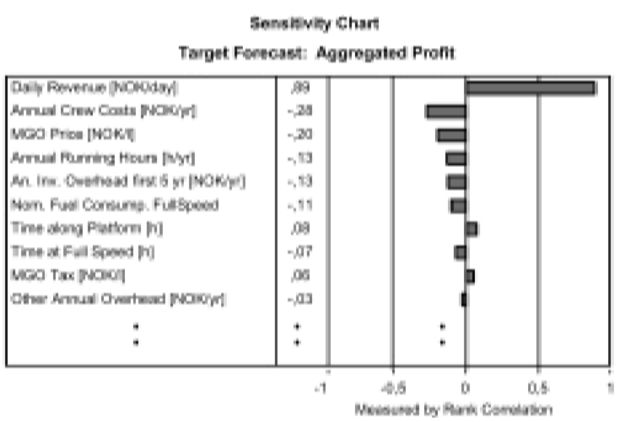


Figure 9
Sensitivity chart for the aggregated life-span vessel profitability



To find out if this is a problem or in fact a logical behavior of the model the sensitivity chart in Figure 6 is studied. Here, it is evident that the different maintenance intervals and the annual running hours play a major role in the sense that they determine the periods in which costs are incurred.

In Figure 7 we see the effect when omitting the maintenance intervals and annual running hours. The abnormal distributions in Figure 5 arise evidently as the registration of costs depends on when the activity is performed, thus giving this large uncertainty in the forecast cells.

This is logic and the model is deemed reliable. The next is to predict future costs and revenues.

4.2 Predicting and tracing critical success factors of future costs and revenues

Figure 5 shows that the maintenance costs trend fluctuates – from approximately NOK 400,000 to over NOK 800,000 per year. However, the trend chart in Figure 8 shows that these fluctuations have little effect on the profitability. The shift in profitability from year four to five is due to the refinancing of the Farstad fleet in 1995.

From Figure 9 we can find which single cost and revenue drivers contribute the most to the life-span profitability. These drivers play the same role in any of the ten years of the operational phase:

- *Daily revenue*. This is the only driver that contributes to the revenues, and is consequently very important to the profitability.
- *Crew cost*. The crew costs is the second most important contributor to the profitability.
- *Fuel related cost drivers*. All these contribute significantly in a negative direction – that is, an increase in these cost drivers will result in a decreased profitability.
- *Annual running hours*. From Figure 9 we see that if we increase the number of annual running hours, the profitability will decrease. This is evident because the more a vessel is running the more fuel and maintenance is required, but the revenue remains the same.
- *An. inv. overhead and interest rate*. These cost drivers determine Farstad Shipping's annual capital costs for this vessel, and are therefore very important.

The other cost drivers in Figure 9 are also significant cost contributors, but since the correlation coefficients are low, we should be more careful with using them right away

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because the method is based on a numerical approximation technique.

For the shipowners, however, the situation is slightly different, because the fuel is provided by the charterer. For Farstad Shipping the profitability trend chart is as Figure 8 except the mean has shifted roughly NOK 3.5 mill. It should be noted that not all the costs are included, due to the system boundaries (see Figure 1).

So what is determining the profitability for the shipowner? From Figure 10 we can see that the main cost and revenue drivers are more or less the same as for the PSV as a whole, except that the fuel related cost drivers have dropped out.

In addition, this sensitivity chart may be unreliable, except for the three top contributors, because how can anything with fuel affect the profitability when the fuel cost is not included in the shipowner's profitability? This will be discussed later, when the main cost contributors are identified.

Figure 10
Sensitivity chart for the aggregated life-span shipowner profitability

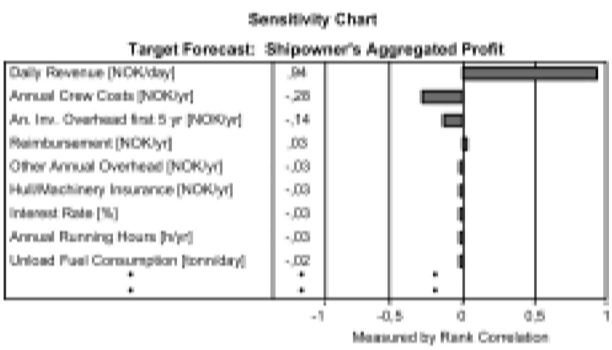
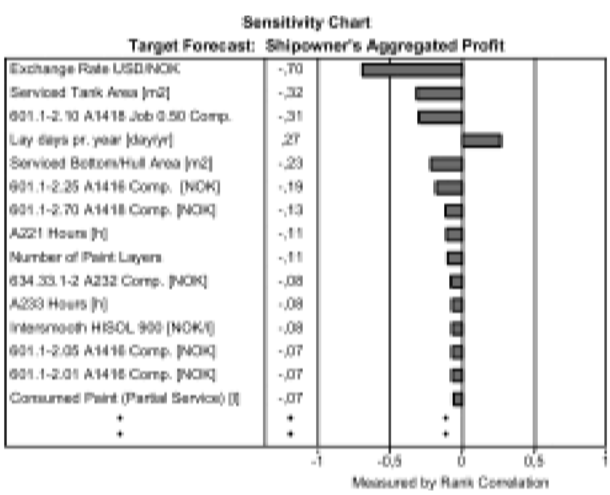


Figure 11
Sensitivity chart for the shipowner's aggregated life-span profitability after eliminating the largest contributors



4.3 Identifying the critical success factors for the shipowner

The reason for the unreliable identification of the other (than the top three) critical success factors in Figure 13 is that the top three are very dominant – especially "Daily revenue", whose correlation coefficient is 0.94. To eliminate this problem, all the large critical success factors already identified are eliminated:

- Daily revenue.
- Interest rate.
- Crew costs.
- Fuel related drivers (if shipowner pays the fuel).
- Annual running hours.
- All the different maintenance and service intervals. These do not affect the total costs for the ten year period significantly, but they highly affect the periodicity of the costs as mentioned earlier.
- Reimbursement for the usage of Norwegian seamen.
- Insurance.

The model is run once more and the results are presented in Figure 11. Now, the "less" important critical success factors can be identified.

In Table III, the 20[3] largest expected cost and revenue contributors to the shipowner's life-span profitability are presented. Table IV is based on the sensitivity charts and starts with the largest first. Please note that:

- The ordering of the contributors may be slightly wrong, and there may be other contributors that should have been listed instead of some of the contributors listed in the table. The probability for this is largest for those in the lower part of the table. Nevertheless, the listed contributors are in any case important.
- We will exclude all cost contributors from the A3 "Repair" activity due to the large amount of inherent uncertainty in those activities.

From Table IV only two contributions to revenues – "daily revenue" and "number of annual lay days" – can be identified. During negotiations with a possible charterer, the different daily revenue and number of annual lay days options can be simulated using the model presented here. Farstad Shipping can then – aided by a trend chart as in Figure 8 – determine which option to prefer, or more actively; Farstad Shipping can determine before negotiations how low daily revenue and how few lay days they can agree upon. In both cases, some of the strength of the model presented here compared to ordinary LCC models w.r.t. prediction, is that future uncertainties can be modeled realistically and taken into account during the negotiations. Table IV can furthermore be used to identify potential areas of saving.

The effect of using different fuel – MGO versus IF 40 HFO – is investigated next.

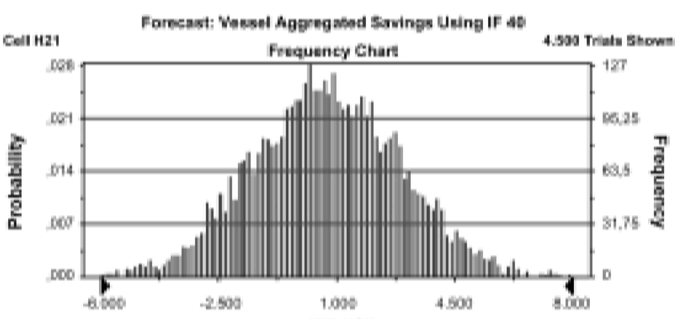
4.4 Investigating design scenario A

As can be seen from the activity network in Figure IV, design scenario A – IF 40 versus MGO – affects mainly the cost of fuel consumption and the cost of consumption of the maintenance activities. In Figure 12 the probability distribution for the aggregated savings of using IF 40 (versus MGO) is presented.

Table IV
The 20 most critical success factors for the shipowner's aggregated profitability

Ranking	Expected cost/revenue contributors	Types
1	Daily revenue	Revenue
2	Capital cost	Cost
3	Crew cost (included reimbursement)	Cost
4	Annual running hours	Cost
5	Other annual overhead costs	Cost
6	Insurance	Cost
7	Different maintenance and docking intervals	Cost
8	Classification (exchange rate USD/NOK)	Cost
9	Serviced tank area	Cost
10	601.1-2.10 A1418 Job 0.50 component cost	Cost
11	Lay days per year	Revenue
12	Serviced bottom/hull area	Cost
13	601.1-2.25 A1416 component cost	Cost
14	601.1-2.70 A1418 component cost	Cost
15	A221 hours	Cost
16	Number of paint layers	Cost
17	634.33.1-2. A232 component cost	Cost
18	A233 hours	Cost
19	Intersmooth HISOL 900	Cost
20	601.1-2.05 A1416 component cost	Cost

Figure 12
Profitability distribution for the aggregated savings of using IF 40 from the vessel's perspective



The model estimates an expected NOK 711,000 saving over a ten-year period, but as can be seen from Figure 12 – if IF 40 is chosen the vessel still has approximately 40 per cent probability of increasing the costs when using IF 40! The choice is therefore difficult; IF 40 is only *expected* to be more cost effective. However, as can be seen from the fuel prices, the fuel consumption and the annual running hours play a major role, thus the IF 40 choice depends on favorable fuel prices, high fuel consumption and low number of annual running hours.

From the shipowner's perspective, however, using IF 40 is highly unprofitable because the consumption of machinery components increases by several hundred percent while the benefits of lower fuel prices cannot be harvested since the fuel is provided by the charterer.

The sensitivity chart in Figure 14 pinpoints the most important maintenance cost factors. Those with negative correlation coefficient are cost drivers associated with the usage of IF 40, and those with positive correlation coefficient are cost drivers associated with the usage of MGO. Hence, an IF 40 system incurs much more maintenance costs than an MGO system.

From the discussion above, the following recommendations are sound:

1 From the vessel's point of view use IF 40 when (otherwise not):
   - the IF 40 price is expected to be favorable in the period;
   - the vessel will be running steady with a high fuel consumption. This can only be achieved when the vessel is going back and forth on full speed, because then the positive effect of high fuel consumption will dominate the negative effect of more annual running hours.

2 From the shipowner's point of view use MGO, except when the shipowner must pay the fuel and point 1 occurs, like when the vessel is on line-charter.

In summary, for the shipowner MGO is best in most cases (unless the charterer specifies something else). The only case where IF 40 would benefit the shipowner is when the vessel is on line-chartering and the IF 40 price is expected to be favorable.

5 Closure

The results from the activity-based LCC include much more information than presented here. But the results presented here do illustrate the comprehensiveness and the effectiveness of activity-based LCC, which is

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the main purpose of this paper. Moreover, activity-based LCC is always workable as long as activities and the belonging drivers can be identified. Also, the modeling of the uncertainty and the usage of Monte Carlo simulations enable designers and managers to effectively and efficiently identify the critical success factors and to present the results more reliably than results from deterministic (uncertainty is not handled) models.

Possible future work should include more design scenarios, and with the Oslo-Paris conventions coming into full effect by 01.01.2005 an interesting scenario would be how to demanufacture a PSV cost effectively.

Figure 13
Sensitivity chart for the vessel aggregated savings using IF 40

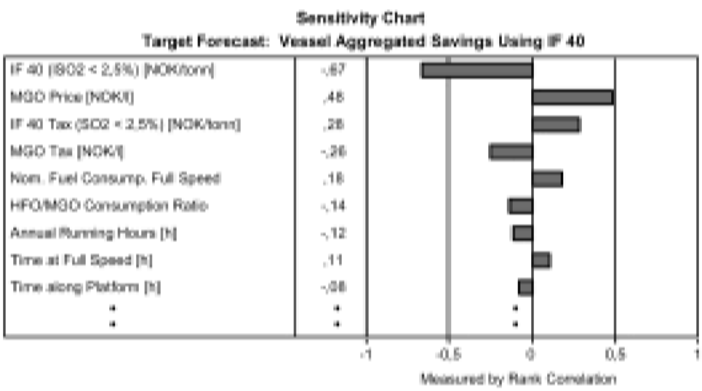
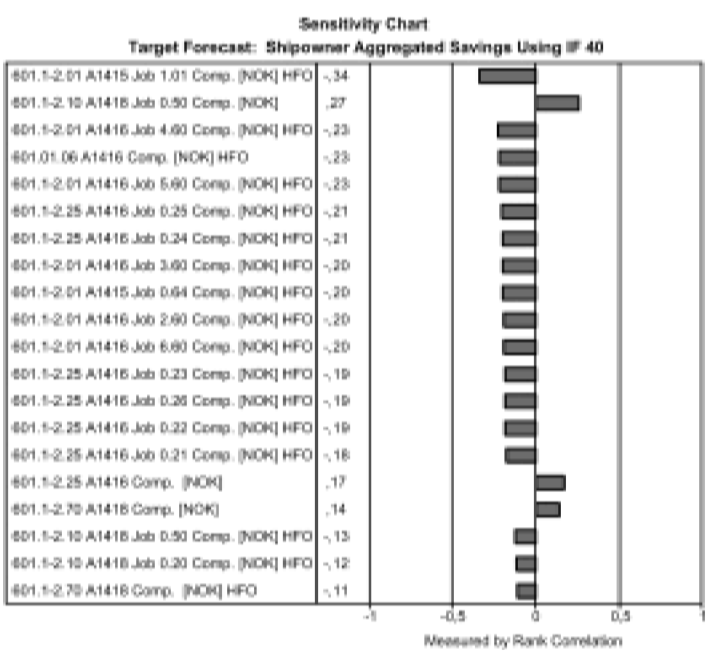


Figure 14
Sensitivity chart for the aggregated savings of using IF 40 from the Shipowner's perspective



Notes

1 In the literature the terms "conventional", "traditional" and "volume-based" are all used interchangeably.
2 There are 501 assumption cells and 65 forecast cells
3 By running more simulations and eliminating the 15 most dominant contributors in each simulation, this table could have been expanded to caputre all the 501 source variables.

References

Allvine, F. (1996), *Marketing: Principles and Practices*, Irwin/McGraw-Hill, Boston, MA.

Brinker, B.J. (Ed.) (1994), *Activity-based Management, Emerging Practices in Cost Management*, Warren, Gorham & Lamont, Boston, MA.

Brooks, P.L., Davidson, L.J. and Palamides, J.H. (1993), "Environmental compliance: you better know your ABC's", *Occupational Hazards*, February, pp. 41-6.

Cooper, R. (1990a), "ABC: a need, not an option", *Accountancy*, September, pp. 86-8.

Cooper, R. (1990b), "Explicating the logic of ABC", *Management Accounting (UK)*, November, pp. 58-60.

Edwards, J.A. (Ed.) (1998), *Handbook of Cost Management*, Warren, Gorham & Lamont, Boston, MA.

Eiler, R.G. and Ball, C. (1997), "Implementing activity-based costing", *Handbook of Cost Management*, B.J. Brinker, Boston, MA, Warren, Gorham & Lamont, pp. B2-1–B2-33.

Emblemsvåg, J. (1999), *Activity-Based Life-Cycle Assessments in Design and Management*, The George W. Woodruff School of Mechanical Engineering. Atlanta, GA, p. 600. The Georgia Institute of Technology, PhD Dissertation.

Emblemsvåg, J. and Bras, B. (2000), "Activity-based life-cycle assessments – a different approach to the ISO 14000 compliance", Accepted for publication, Kluwer Academic Publishers.

Emblemsvåg, J. and Bras, B.A. (1994), "Activity-based costing in design for product retirement", *Proceedings 1994 ASME Advances in Design Automation Conference*, DE-Vol. 69-2, American Society of Mechanical Engineers, Minneapolis, MN.

Fet, A.M., Emblemsvåg, J. and Johannesen, J.T. (1996), "Environmental impacts and activity based costing during operation of a platform supply vessel". Ålesund, Norway, Møreforsking, December, p. Å9604.

Greenwood, T.G. and Reeve, J.M. (1992), "Activity based cost management for continuous improvement: a process design framework", *Journal of Cost Management for the Manufacturing Industry*, Vol. 5 No. 4, Winter, pp. 22-40.

Hanssen, O.J. (1998), "Sustainable product systems – experiences based upon case projects in sustainable product development",

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Journal of Cleaner Production, Vol. 7 No. 1, pp. 27-41.

Hardy, J.W. and Hubbard, E.D. (1992), "ABC: revisiting the basics", *CMA Magazine*, November, pp. 24-8.

ISO/TC 207/SC 5 (1996), *Environmental Management – Life Cycle Assessment – Principles and Framework*, International Organization for Standardization, ISO/CD 14 040.

Miljøverndepartementet (The Royal Norwegian Department for the Environment) (1995), Om samtykke til ratifikasjon av en konvensjon om beskyttelse av det marine mijlø i det nordøstlige Atlanterhav, undertegnet i Paris 22. september 1992. (An agreement about ratification of a convention regarding the protection of the marine environment in the northeastern Atlantic Ocean, signed in Paris 22nd of September 1992). Oslo, Norway, Miljøverndepartementet (The Royal Norwegian Department for the Environment), St. prp. nr. 39.

O'Guin, M. (1990), "Focus the factory with activity-based costing", *Management Accounting*, February, pp. 36-41.

Park, C.S. and Sharp-Bette, G.P. (1990), *Advanced Engineering Economics*, John Wiley & Sons, New York, NY.

Wood, J.C. (1998), "Environmental impacts on life cycle costs", in *Handbook of Cost Management*, Edwards, J.A., Warren, Gorham & Lamont, pp. D6-1–D6-30, Boston, MA.

Glossary

Lay day: The days specified in the contract when necessary repair, service and maintenance can be done.

Maintenance: Here it refers to all maintenance activities done while the vessel is in service (see "Service").

Off-hire: The vessel is incapable of fulfilling the contract – planned or not (definition is provided by Technical Manager Jan Henry Farstad). In the contract between the shipowners and the charterer this is specified in detail.

Repair: Unplanned service.

Service: Planned maintenance activities that require the vessel being out of service. How often the vessel is docking depends on the policy of the shipowner, but the vessel has to be docked every five years due to class specifications given by Det Norske Veritas.

SFI (Skipsforskningsinstituttet) Grouping System: This grouping system is distributed by Norwegian Shipping and Offshore Services AS. It is the most common system in Norway.

Uncertainty: Applies to situations where we do not have good probability information. Risk, in contrast, applies only to situations for which the outcomes are not known with certainty but about which we have good probability information. Hence, uncertainty is the general term.

UT 705: A specific type of platform supply vessel designed by Ulstein International AS capable of:
- transporting pipes, cement, equipment and goods to and from pipeline barge, oil rig and ships;
- load and laying beside a pipeline barge under North Sea conditions with approximately 4.6 meter high waves and a tidal current of roughly 3.5 knots.