

MODELLING ‘HARD-TO-MEASURE’ COSTS IN ENVIRONMENTAL MANAGEMENT ACCOUNTING

Michael Falta*

Lynn Gallagher

School of Accountancy

Queensland University of Technology

Brisbane, Australia

Roger Willett

College of Graduate Studies

University of Wollongong

Dubai

Abstract

This paper reviews measurement issues that have arisen in the environmental management accounting literature and provides a statistical approach to quantifying the financial results associated with vaguely defined outcomes from physical processes. Among the latter are outcomes relating to safety and pollution both of which also impact on political visibility. A classification of ‘hard-to-measure’ costs is given with illustrations of how mathematical modelling allows these to be estimated and their implications for decision-making better understood. Our approach provides an integrated analysis of return and risk.

Keywords: Computational Statistics; Forecasting; Environmental Management Accounting; Modelling; Uncertainty

Introduction

The purpose of this paper is to provide a measurement focus to the modelling of certain hard-to-measure costs in an environmental management accounting context. The problem of measuring social cost is a challenge for accountants. There is a reluctantly-acknowledged view that it is desirable to consider social and environmental costs. However, in practice these costs are consistently treated in financial accounting reports, and have seldomly been included in management accounting reporting. As explained by Gray (1990, p. 213):

“The accounting professions’ experience with social accounting in the 1970s suggests that, if history repeats itself, we can expect a lot of interest, speculation, warm words and controlled debate, but very little action or commitment.”

There are various reasons for this reluctance to include environmental costs in management accounting¹, all of which relate to the particular environmental costs addressed here:

- at the time of production, it is not usually possible to identify potentially relevant future ecological and social issues (they are either unknown, or they are contingent on the occurrence of a particular event);
- the existence of externalities; and
- where environmental costs are evident, they are frequently difficult to measure in financial terms (Benston, 1982). These measurement problems impede the task of environmental management accounting.

Environmental costs include the costs incurred by an organisation to prevent, monitor and report environmental impacts (Langfield-Smith *et al.*, 2005), and extend further to costs contingent on the occurrence of an uncertain event. While some environmental costs are relatively easy to measure (e.g., purchasing capital equipment to reduce the amount of toxic emissions or costs of complying with regulations), others are less certain. It is the difficulty of estimating hard-to-measure environmental costs that is in part responsible for the failure of management accounting to incorporate environmental costs in management accounting reports in a structured way.

This paper considers the measurement of two environmental costs related to uncertainty:

- employee safety in the blending process of a food production firm; and
- pollution resulting from the use of marine assets.

The uncertainty surrounding *employee safety* costs relates to the need to estimate the probability of a breach of the safety procedures, and the difficulty of predicting the magnitude of possible costs in the event of an accident. Firms today are seen as being increasingly accountable to parties other than the owners. Interested stakeholders include employees, customers, suppliers and the broader community in general. From an accounting perspective, this has been made explicit in triple bottom line reporting, and there is a view that failure to take social responsibility seriously impedes a firm's long-term survival (Simms, 2002). However, it is one thing to acknowledge that environmental management accounting is important - it is another thing to find models capable of validly estimating uncertain and contingent environmental costs. The model proposed illustrates how this measurement task can be achieved.

Difficulties in measuring *pollution* costs relate primarily to the existence of externalities. Externalities occur when the costs are not confined to the producer, making it difficult to enforce compensation when pollution occurs. Further, it is

usually not possible to charge an additional price to consumers who benefit from 'cleaning up' polluted waterways, because it is impractical to restrict consumption of the product (unpolluted waterways) to purchasers. Despite this, Burritt and Gibson (1993) note that there are financial incentives in terms of for firms to care about reducing marine oil pollution.

“ship loss or repair, value of the oil spilt, clean-up and equipment, legal costs and fines or monetary penalties, civil and criminal damages, and insurance premiums”

Existing management accounting techniques have proven to be useful in measuring some environmental costs (techniques such as Activity-Based Costing and Life-Cycle Costing (IFAC, 1998; see also Gluch and Baumann, 2004), and the quality cost framework (Langfield-Smith *et al.*, 2005). However, they have been of limited usefulness for uncertain environmental costs those relating to pollution and employee safety. This paper uses statistical analysis to assess such costs.

Literature Review

There has been a debate within academic and professional accounting circles regarding the relevance of social accounting for many years but developments in environmental accounting disclosure have gathered momentum over the past three decades due to increasing societal demands and regulations (Kitzman, 2001). Prior research in the area has primarily been descriptive in nature, explaining what firms have been doing (Parker, 2000), or more particularly, what firms have not been doing (Gray, 1990). In the early days the introduction of environmental accounting was motivated by a belief that voluntary disclosure was preferable to government regulation (Sethi, 1973). However, the effectiveness of achieving corporate accountability via financial accounting reports is problematic (Benston, 1982). More recently, environmental accounting research has focused on triple bottom line reports (Colman, 2004): involving formal accounting reports of not only a company's economic performance, but of environmental and social best practice and compliance. There is, however, general consensus that before social and environmental bottom lines attain the external significance of the financial bottom line, they need to be measurable and standardised (Cheney, 2004).

Though disclosure requirements of external reporting are not our major concern here, we are interested in a particular subset of environmental accounting, namely Environmental Management Accounting (EMA). EMA aims to identify, measure, analyse and allocate environmental costs to products, for the purpose of improving both financial and environmental performance (Gibson and Martin, 2004, p. 45). There is general agreement that EMA is the key to firms seeking to reduce environmental costs, improve profitability (Gibson, 2003) and add value to the company (Kitzman, 2001). However, the track record of EMA is no more

impressive than environmental accounting generally. A management accounting survey of Australian companies (Gadenne and Zaman, 2002) reports that very few companies in Australia are measuring environmental costs in either quantitative or qualitative terms. Cheney (2005) describes EMA as haphazard and unguided, with firms generating methodologies for their individual requirements, but with no comparable consistency. A lack of appropriate measurement techniques (Herbohn, 2005) and a lack of a comprehensive framework on which to map existing EMA tools and measure environmental costs hinders the more widespread use and adoption of EMA (Burritt *et al.*, 2002).

A search of the literature revealed the following examples of *ad hoc* measurement tools used by firms implementing EMA. Typically corporate accounting practices submerge environmental costs in general overhead (Rogers and Kristof, 2003). Cairns (2004) uses shadow prices when investigating pollution at a mine. Danielsson (2005) describes measures used to value the exploitation of fishing stocks. The use of proxy metrics to measure externalities is discussed in Benston (1982). Using discounted cash flows has been classified as an inappropriate measurement tool for environmental costs (Burritt and Lodhia, 2001). A Systematic Accident Cost Analysis project to measure the cost of occupational accidents (Rikhardsson, 2004) is yet another example of an isolated measurement tool designed for particular situations in environmental costing.

A number of studies promote activity-based costing, life cycle costing (or full costing), and the quality cost framework for the analysis of environmental costs in EMA.

Activity-based costing is useful in costing some of the more certain environmental costs, attempting to charge cost directly to products rather than via a general allocation of overhead (Kreuze and Newell, 1994; Rogers and Kristoff, 2003). Life cycle costing (also described as full environmental costing) recognises that product costs extend from research to disposal, and that frequently a large proportion of the costs are committed by the design stage (Kreuze and Newell 1994; Cheremisinoff, 2002; Antheaume, 2004; Cleary *et al.*, 2005). It has been claimed that EMA has improved with full environmental cost accounting and contributed to improving corporate performance, reducing corporate environmental impacts and increasing long-term corporate profitability (Epstein, 1996).

Another management accounting technique is the framework for analysing quality costs (Langfield-Smith *et al.*, 2005). In a total quality management framework, costs of quality are classified as prevention, appraisal, internal failure and external failure costs (Smith, 1990). Firms moving towards total quality introduce additional costs at the prevention and appraisal level, with a view to significantly reducing

quality costs overall, based on the premise that prevention costs are less than correction costs. This is premised upon critical costs of a firm being external failure costs, which are often difficult to define, and frequently significant because of the multiplier effect of hidden costs when external failure occurs. In the ideal quality world, firms would spend all quality costs on prevention and zero on the other three elements of quality (Hughes and Willis, 1995; Kitzman, 2001). EMA has developed with these approaches but there is no agreed measurement technique useful for measuring uncertain environmental costs.

The analysis that follows addresses this deficiency using a statistical approach to accounting measurement based on Willett (1987, 1988, 1991). Articles that use this approach divide into purely statistical analyses (e.g., Lane and Willett, 1999; Su, 2004), simulation studies (e.g., Hillier, 1998), papers that conceptualise the idea of a virtual firm (e.g., Gibbins and Willett, 1997) and statistical modelling of the 'virtual firm' (Falta, 2005). Falta and Wolff (2004) give a complete review of this literature and provide for its mathematical representation. The application of this approach to accounting measurement in EMA is explained in the next section.

Framework and Method

A central proposition of Willett's approach to modelling businesses is the separation of the physical and financial parts of the overall structure. Only after the physical input-output relationships of processes are understood can the financial effects of the processes be accurately modelled and assessed. The application of it in traditional management accounting is to problems involving the costs of inputs such as materials, labour and equipment. However, safety, pollution, social and other environmental aspects are concomitant outcomes of business processes with a steadily growing importance in the public perception.

To illustrate, consider, for example, a manufacturing process rather than, say, the service industry. Inputs usually include labour, materials and consumable resources, fixed assets (e.g., machinery, premises) and knowledge. These are 'consumed' through tasks that generate corresponding outcomes that can include, at various degrees, some of the concomitant factors. For the latter we may distinguish between their occurring prior to or after the accomplishment of the (physical) product as, for example, a change of ownership might occur. This will be discussed below in the pre and post-production stages separately.

During the Production Process

The structure of observable physical processes determines the numbers K and M of inputs and outputs for the main product. With the physical structure in place, all

concomitant factors can be incorporated. Each of these occurs in various degrees at each output node and might trigger additional inputs determined by physical requirements.

Practical implementations of the above approach rely on a careful identification of all processes and their follow-up effects. The more accurate the physical measurement of the traditional, safety and environmental inputs and outputs, the more accurate the cost analysis.² Physical measurement of variables such as the time of exposure (personnel), time of transport (resources), time of operation or quantity of consumption (machinery, resources) can be accurately assessed. Their costs can then be derived based on transactions data or through estimation and forecasting procedures.

Post-Production Considerations

Post-production safety, social and environmental aspects can have markedly different properties compared to their respective pre-production counterparts. Safety issues, for instance, include the operation of a product with poor publicity resulting from unreliable or faulty items. Impacts on public relations then may trigger post-productive corrections to the cost of the producer. Environmental pollution, another post-productive aspect, requires cleaning-up operations and damage control. These successive activities, albeit being more vague to place in time, nevertheless can be represented according to the usual input-output relationships discussed in Section 3.1 as their existence is indisputable.

The identification of post-productive input-output relationships is important to a producer as damages payments are usually high. These follow-up inputs for which the producer can still be liable in form of environmental subsidy payments. Even if the product changes ownership, the producer may still be liable for costs arising from future events (through, e.g., warranties, contracts).

Note that a set of outputs may be subject to different time-scales. For example, radioactive waste disposal and safety considerations during a production process are quite distinct. The analysis of these concomitant aspects of management accounting therefore necessarily involves a combination of appropriate forecasting models next to the methodology proposed in this work.

Comments, Implementation and Some Case Studies

We shall focus on a discussion of two case studies and deduce from there the general applicability of our approach. Below, we introduce the different scenarios which differ from one another through the type of business considered, the time period (past, present and future) and the type of concomitant process. A list of alternatives that can be investigated arise from the given setting of both scenarios

for which, in Section 4, we use fictitious and censored data and present the results.

Safety - Blending Machinery in Food Industry

The following example of a blending process is a typical sub-process found in applications of industrial production processes. Aside of the actual physical process, we consider safety issues for personnel, machinery and resources.

The sub-process consists of the following tasks. Two different raw materials A and B are transported from a storage area to the blending machine in order to be processed. The first intermediate output is a filled blending machine, with labour, material and machine the necessary inputs. The blending process then consumes energy and, finally, for the packing process, material and labour are used up in order to produce sealed bags with the desired AB product-mix.

Each output has accumulated some degree of employee-related safety risk as has been identified at each output node.

Pollution - Marine Assets

Here, we present the statistical cost estimation in a life-cycle ownership framework and consider additionally the environmental aspect of pollution. The fuel consumption of large marine vessels with regular annual operating durations translate to fuel costs which are in the order of millions of dollars and account for a considerable proportion of total operating costs. The estimation and prediction of fuel consumption is therefore an important aspect of ship management and so is the resulting environmental aspect of pollution as there are, at any instant of time, hundreds of large (commercial and naval) vessels operating at sea. Fuel consumption depends on the hydrodynamics of ship resistance, the efficiency factor of the propulsion system and natural forces. Thus, ship specific parameters (design, type of propulsion, cargo and draft, and ship condition), ship speed (pitch and plant configuration, e.g., single engine, two engine or four engine), wind direction, sea condition, water currents, water depth, and temperature are important factors.

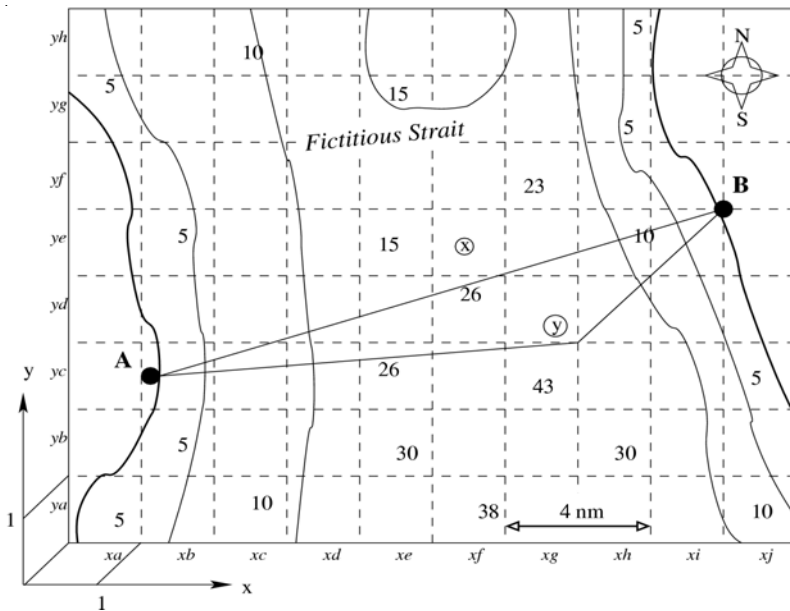
We apply Hellström's (2004) model of fuel consumption to a ferry that operates between two ports A ($x = 1.25, y = 2.5$) and B ($x = 9, y = 5$) on route x in the Fictitious Strait as displayed in Figure 1. In the model, the ship's route is discretised into n route legs each of which is specified by a constant depth d_p , current conditions $c_{long,i}$ and $c_{trans,i}$ [4] and the length s_i that the ship travels within the leg. Global constraints are the allowable ship speed and the total journey duration (wind conditions are not considered here). Thus, the fuel consumption F_i on leg $i, i = 1, \dots, n$, is given by

$$F_i = \frac{S_i}{x_i} * S(x_{w,i}) * (1 + \frac{D(x_i, d_i)}{100}) + \epsilon_i, \tag{1}$$

where S is the speed model that correlates ship speed through water x_w given the impact of transversal and longitudinal water currents and the relative speed over ground x_i ; the depth model D relates water depth and speed as the water resistance in shallow waters reduces ship speed due to the squat effect (Härtig and Reinking, 1999); the disturbance term ϵ accounts for the variation of the effect of wind on the ship's fuel consumption. Alternatively, ϵ can also be seen as the variation of the fixed model-parameters at single legs.

Expression (1) can be used to calculate optimised speeds $x = (x_1, \dots, x_n)$ [3] for which Hellström (2004) presents three start value algorithms. The expression can also be used to find an alternative route y (cf. Figure 1) which satisfies given constraints and has minimal fuel consumption and therefore minimal fuel costs and pollution. In general, let $C_i(F_i)$ be the cost for the consumed fuel F_i . Then, the total fuel cost $C(F)$ for a specified number of operating days is a random sum over N legs of random variables C_i .

Figure 1 Fictitious Strait



Note: Sea map with ferry routes x (current) and y (alternative) between ports A and B. Distances are given in nautical miles ($1 \text{ nm} = 1.852 \text{ km}$)

Results

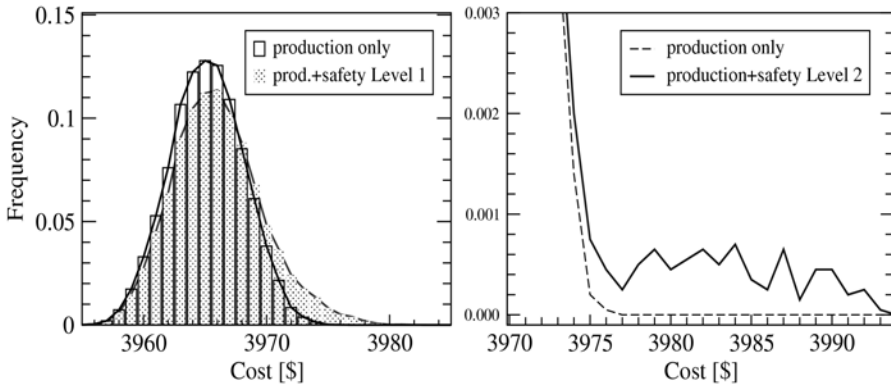
Safety - Blending Machinery in Food Industry

Assume that management has established the following properties for the blending process. Firstly, for the actual production process, $1t$ of product A and $0.5t$ of product B are mixed per batch. Purchase price for A is $\$2,000/t$ and for B $\$3,500/t$. Mean distances of product A and B from the blending machine are $70m$ and $30m$, respectively. One employee operates a forklift, which, on average, runs between storage and machinery at a speed of $10km/h$ with a maximum loading capacity of $250kg$. Loading time for both resources is between $25s$ and $35s$, durations for unloading, unpacking and filling of the blending machine are between $2min50s$ and $3min10s$. The blending process runs for $2h$ with an energy consumption of $400kWh/t$ at a price of $\$.03/kWh$. The final package weight is $150kg$ with a duration between $9min30s$ and $10min30s$ for all 10 bags to be filled and sealed. Bags are bought in bulk and the per unit price is $\$10$. Wages for any kind of labour are $\$25/h$.

Secondly, with respect to employee safety, three risk levels have been identified: Level 1 resulting from shed loads with no direct health consequences, but increasing the pressure on employees to meet daily quotas; Level 2, for minor injuries like sprains or cuts which interrupt the production process; and Level 3, for major injuries. From experience, safety risk Levels 1 and 2 are associated with O_1 and O_3 and all three risk levels with O_2 . Management has recorded incidents for each risk category with the following outcomes. Incidents that fall into risk Level 1 occur, on average, every $5h$ and those which fall into Level 2, on average, every $80h$. For risk Level 3, there have been only 3 recorded incidents since the blending process was put into operation three years ago. For each risk category, the production has been put behind schedule for durations between $5min$ and $20min$ (Level 1), between $10min$ and $60min$ (Level 2), and for 45 , 120 and $180min$ (Level 3). Costs associated with the delays include, for Level 1, additional labour costs for overtime, for Level 2, overtime pay and additional costs for on-site first-aid material. These are estimated at $\$30$ per case and in 50% of the cases further medical attention from a paramedic at a cost that is approximated by a Normal distribution with mean $\$150$ and variance $\$50$. The three Level 3 incidents incurred additional administrative and emergency workforce drafting costs, besides the costs that account for the production delay, of a total of $\$800$, $\$620$ and $\$2500$ (includes costs for legal advice).

The above information contains events, their durations and (estimates of) costs that ought to be available in practice. Here, data are generated for 100,000 instances

Figure 2[f4] Comparison of Costs for a Blending Process



Note: Safety costs impact on production costs in two ways - higher expected cost and larger variation of costs.

of the entire blending process in a static (no time connection between successive blending activities) simulation setting. The results are displayed in Figure 2 in form of the realised cost distributions and show the variation of the total cost to process one batch of A and B ingredients in a food-mix according to the physical structure described above.

On the left of the figure, the impact of Level 1 safety breaches shifts the batch costs from \$3,965.17, the amount if safety impacts are not considered, to a sample mean of \$3,966.01. As processing one batch usually takes less than 2 1/2h, the difference of \$.84 adds up to large amounts on a monthly basis, certainly sufficient to be noticeable to a decision-maker. More interesting, however, is the fatter upper tail of the sample distribution that includes safety Level 1 incidents for it allows us to perform risk analyses.

Assume that management has calculated that each batch costing more than \$3,971.00 generates zero profit. The probability that the cost for a batch is higher than this crucial mark, due to Level 1 safety incidents, is 9.26% as opposed to an acceptable 2.35% if safety costs are not considered.

Similar results are displayed on the right of Figure 2 where Level 2 safety costs are displayed. Due to the frequency of occurrence being significantly lower than in the Level 1 case, the difference in the frequency distribution is negligible if considered over the same range as on the left hand side graph. We have therefore highlighted the right hand side tail which clearly shows that some batches cost well above the \$3,977 mark, which is the maximum production cost.³ It is these few costly incidents that are responsible for the average costs being \$3,965.33

(Level 2) and \$3,965.79 (Level 3, not displayed). The probabilities of lying above the \$3,971.00 benchmark are 3.28% and 2.39%, respectively. In such circumstances, management should focus on lower Level 1 safety costs as Level 2 and Level 3 safety costs have a smaller impact on average batch costs over the period of three years.

Pollution - Marine Assets

We assume the following information about the current ferry operating process on route x during one day. The first departure at A is at 05:00 with the last arrival at the same port at 00:30. The scheduled passage in both directions is $2h$ with a loading time at both ports of $1/2h$. During the latter the engines operate at a minimum intensity and do therefore not account for this fuel consumption. The four return passages are exposed to different sea conditions as the tidal currents, for a particular day of our analysis, push waters north during high tide (max $4kn^4$ at 10:00 and $2.8kn$ at 22:00) and south during low tide (max $3kn$ at 16:00 and $2.8kn$ at 04:00). Turning points for the north-south tidal currents are at 07:30, 13:30, 19:30 and 01:30. The sea depths given in Figure 1 mark the yearly average between the two tides. The maximum sea level changes are as follows: $+2m$ and $+1m$ for high tides at 10:00 and 22:00, and $-1m$ for low tides at 16:00 and 04:00, respectively. Values for both the sea currents and sea depth for other times during the day than those given above have been linearly interpolated.

Speeds through water relatively to ground, measured independently of water depth, and additional fuel consumption due to shallow waters at different speeds are given in Table 1. Actual speeds w through water are calculated according to sailing direction and water currents using vector calculus. The ferry is limited to a maximum speed of $3kn$ while operating in coastal waters.⁵ Its maximum speed is $23kn$. Assume that fuel (e.g., high quality bunker oil) can be purchased at a price of \$200/1,000l.

The fuel consumption calculations account for

- constraint 1: the scheduled operating hours;
- constraint 2: the coastal speed restrictions;
- changing fuel consumption due to the varying current speed and direction, at different times, which can be calculated with vector trigonometry;
- changing fuel consumption due to the sea level topography; and
- changing depths of the sea level topography due to the tides, at different times.

We have applied the above model to expression (1) in two different scenarios each of which has been simulated 10,000 times. In each scenario, our algorithm⁶ first calculates the direction according to the planned route for each leg given the

Table 1: Ferry Data

speed over ground x	consumption l/h	speed over ground x	depth d	% fuel increase
5	450	10	5	7
8	600	10	10	4
10	720	10	50	1
12	880	15	5	60
14	1080	15	10	50
16	1300	15	50	3
18	1700	23	5	65
20	2250	23	10	52
23	3000	23	50	1

Fuel consumption for varying speeds over ground and additional fuel consumption due to shallow waters. Values in between these points are estimated by a linear and a bilinear interpolation, respectively.

forseeable weather conditions and adjusts the effective ship direction according to the current.

Case 1. Current operating plan on route x . The ferry sails at $3kn$ in coastal waters according to marine speed limitations and covers the remainder of the passage at an average speed in order to arrive punctually at the other port. This average speed changes according to the tidal currents and is calculated for an average current speed, which is observed during the time the vessel traverses the middle part of the passage.

Case 2. Alternative operating plan via route y . The direct route x passes over a maximum water depth of $26m$ and it is suspected that the fuel increase due to the squat effect may be considerable. Route y , which goes over deeper waters (maximum depth is $47m$) south of route x in the Fictitious Strait could minimise the increased fuel consumption due to the squat effect. Route y , therefore, needs to be considered as an alternative to route x .

Case 3. Optimised operating plan using both routes x and y according to tidal currents. In an optimised operating plan we compare the fuel consumptions of both routes and propose to choose between x or y according to a minimal fuel consumption criteria.

In Table 2, we display a selection of output data from our simulations for the 05:00 to 07:00 passage via route y . The table contains (1) the leg number and leg coordinates (cf. Figure 1), (2) the planned travel length through each leg, (3) water depth adjusted for tidal water level changes (in brackets), (4) speed of tidal current, (5) vessel's planned speed and true speed through water, (6) fuel increase

Table 2: Exemplary Output of Ferry Route Data

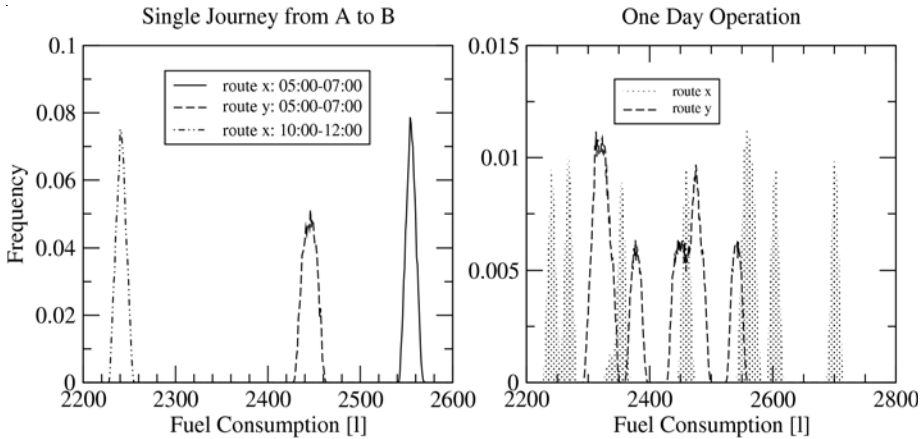
leg	leg coord	s_i	water depth	speed of tidal current	planned speed	vessel: true speed	fuel increase	fuel
		[nm]	[m]	[kn]	[kn]	[kn]	[%]	[l]
1	(xb,yc)	1.5056	4(-1)	2	3	3.70	125	265.53
2	(xc,yc)	2.0076	25(-1)	2	18.38	19.48	132	279.86
3	(xd,yc)	2.0076	35(+0)	1.6	18.38	18.64	120	264.94
4	(xe,yc)	2.0076	40(+0)	1.6	18.38	18.62	113	244.17
5	(xf,yc)	2.0076	47(+0)	1.2	18.38	18.61	105	243.89
6	(xg,yc)	2.0076	47(+0)	1.2	18.38	18.59	105	260.85
7	(xh,yd)	2.8284	30(+0)	0.8	18.38	18.58	126	438.05
8	(xi,ye)	2.8284	5(+0)	0.8	3	3.64	125	339.56

Output for the 05:00 to 07:00 passage on route y . Given are the eight legs which the ferry traverses, sea conditions and fuel consumption. The water depth shows that the 2h journey takes place between low and high tides (signaled by no alteration of the average values shown in brackets).

due to shallow water and (7) the fuel consumption. Note the considerable fuel increase due to the squat effect in shallow water. We further observe that with decreasing speed of the tidal current, the true speed of the vessel slows down correspondingly. Of further note is the high fuel consumption in the last two legs, which is due to the vessel's frontal direction against the current.

The main results are displayed in Figure 3. The left graph in Figure 3 shows the fuel distribution for the 05:00 to 07:00 passage via routes x and y and the 10:00 to 12:00 passage via route x . In general, the variation of fuel consumption is generated through parameter [epsilon], which accounts for a combination of random wind forces that impact on the ship's speed and the steadily changing speed of tidal currents during the time that the vessel spends in a particular leg. During this passage via route x , the northerly tidal current retards the planned speed of the vessel such that the fuel consumption is increased due to higher true speed through water and due to its more frontal direction. The average fuel consumption for the 05:00 to 07:00 passage via route x is 2,554.1l (standard deviation 26.03l) which is significantly higher than for the alternative route y of 2,444.49l (25,42l). Although route y is longer and consequently must be the planned speed, it goes over deeper waters and has a more favourable angle with the northerly tidal current. Comparing the 10:00 to 12:00 passage leaving port A for port B (identical to the earlier passage) the considerable effect of tidal currents on the fuel consumption along the same route x , now with only 2240.38l (23.0l) fuel spent, has also been displayed.

Figure 3: Fuel Consumption Distributions



Note: Left: impact of different environmental conditions on the fuel consumption distribution for a single passage from A to B. Right: multi-modal distributions for 10,000 equivalent operating days for alternative routes *x* and *y*.

The right graph of Figure 3 shows two multi-modal distributions for the fuel consumption during the particular day. Operating the vessel along route *x* results in an average of 2467.86l (158.0l) and along route *y* in an average of 2408.87l (84.13l). As the pattern of tidal currents changes on a yearly basis, considering a longer duration of operation leads eventually to a uni-modal distribution. Here, however, it is not only the 58.99l of unnecessarily spent fuel for the day (on average) but also the fact that the variation of fuel consumption is almost half for the alternative route *y*. This last result is important for decision-making, for example, in the case of fuel buying strategies and fuel storage considerations.

For Case 3, the fuel consumption of 2,393.72l (103.18l) is slightly lower than for route *y*, as given above. This results from the following route itinerary: 10:00 to 12:00 (A to B) and 20:00 to 22:00 (A to B) via route *x* and all other passages via route *y*.

In monetary terms, the fuel savings are \$11.80 (route *y* over route *x*) and \$14.83 (optimal combination of passages over route *x*). Over a vessel's life time (possibly two or more decades) operating all year round, these small differences add up to significant amounts. The environmental damage of increased pollution due to sub-optimal route planning can be assessed in terms of the quantity of unnecessarily fueled bunker oil: the relative difference of 74.14l or 3.01% results in additional environmental costs.

In a final remark note that absolute costs of pollutant emissions such as carbon and nitrogen oxides have been published by Externe studies in the European Union (European Commission, 1997). For example, CO₂ emissions in the 95% confidence interval range from \$0.005kg⁻¹ to \$0.19kg⁻¹. This data has been used in, for example, vehicle retirement decisions (Spitzley *et al.*, 2005) or investigations of alternative energy sources (e.g., Mercuri, Bauen and Hart, 2002).

Summary

In this paper we have illustrated how a statistical cost analysis can be applied to measurement issues that have arisen in the environmental management accounting literature. Two scenarios were used: firstly, we assessed costs that originate from safety issues during a blending process in the food-preparation industry and, secondly, we considered environmental pollution resulting from a ferry operation. In order to assess these hard-to-measure concomitant costs and quantify their impact on return and profit, we have separately modelled physical and financial business processes. This approach is (1) applicable to any type of business, (2) indispensable in order to be able to account for uncertainties of production processes, task durations, the quantity of inputs and outputs and associated costs and (3) necessary for good decision-making that incorporates sophisticated risk analysis.

When we derive relative costs from corresponding distributions, statistical analysis enables us to extract information about each component of the total cost that is potentially useful for decision-making in conditions of uncertainty. Some absolute costs for pollutant emissions per unit weight have been published in European Commission studies. These values can be either directly plugged into our results or used as decision-aid in the planning of, for example, shipping routes.

Research is being directed to implementations of business processes using real world data. Both examples in the scenarios described in the paper are part of ongoing projects undertaken to achieve this objective. This brings together aspects of many disciplines such as finance, accounting and economics, operations research, engineering, programming, physics and chemistry.

Notes

- * Corresponding author: m.falta@qut.edu.au
- ¹ The reluctance is even more pronounced in financial accounting reports, but financial accounting disclosure is not the focus of this paper.
- ² The quality of measurement depends on two factors, firstly, whether or not there are regulations in place which companies have to comply with, and secondly, the interest of the business in freeing resources for such an assessment.

- ³ The frequency distribution for Level 3 safety costs has a spike that lies much further to the right.
- ⁴ $1kn = 1knot = 1.852km/h = 1nm/h$.
- ⁵ For Fictitious Strait, coastal waters are defined as quadrants which partly contain landmass, for example, (xb,yc) and (xb,yb).
- ⁶ The algorithm is implemented in C. Five functions double fuelIncrease DueDepth (double,double), int depth_change (double), double speed Currents (double,double), double trueSpeed (double,double,double) and double base Fuel Consumption (double) are inputs to the main program that controls the directional calculations (passages A to B or B to A) and additional leg properties such as passage distance and the time structure.

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The **Asia-Pacific Management Accounting Association** (APMAA) was established in 2004 as an international academic organization with special focus on management accounting of the Asia-Pacific region. The proposal to form the Asian Management Accounting Association was first mooted at the convention of Asian Management Forum, which was held on 3rd and 4th November 2002 in Japan. Since that time, the participants from different countries continued to share the same vision of advancing management accounting research and practices with particular reference to the Asia-Pacific region. As a result, when the second convention, Asia-Pacific Management Accounting Forum was held on 24-25, November 2004 in Malaysia, it was unanimously decided that the time had arrived to establish the **Asia-Pacific Management Accounting Association** with two main objectives.

1. The objective of APMAA is to promote the advancement of management accounting theory and practices with particular reference to Asia-Pacific accounting issues.
2. For this purpose, APMAA shall undertake to organise forums and conferences, and the publication of the journal: *Asia-Pacific Journal of Management Accounting*.

The 3rd **Asia-Pacific Management Accounting Forum** was held in Fukuoka, Japan in March 30-31, 2006. The main theme of the Forum was *Present and Future of Management Accounting*. The forum attracted more than 40 participants from China, Korea, Japan, Malaysia, Singapore, Taiwan and Hong Kong. Professor Akira Nishimura, the President of Asia-Pacific Management Accounting Association (APMAA), gave the opening address. A total of 8 papers were presented, with topics ranging from theoretical and practical development of management accounting to corporate governance in the Asia-Pacific region.

The Steering Committee of APMAA held a meeting at the end of the Forum. One of the decisions made during the meeting was that the 4th Asia-Pacific Management Accounting Forum would be held in Chengdu, Sichuan Province, China sometime in mid-April, 2007.

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