Integrating activity-based costing and environmental cost accounting systems: a case study

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Abstract: The integration of activity-based costing (ABC) and environmental cost accounting (ECA) systems provides companies with more accurate information to make both well-rounded and effective decisions. The purpose of this study is to propose an effective approach to integrate both ABC and ECA systems. A case study analysing process is used to compare the traditional accounting system and the ABC system for allocating environmental costs. The results enable managers not only to understand financial information regarding the activities for environmental protection and the percentage of environmental costs in the overall product costs but also to make more objective and accurate decisions.

Keywords: ABC; activity-based costing system; ECA; environmental cost accounting system; LCEC; life cycle environmental cost; green accounting.

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1 Introduction

Modern manufacturing companies are facing a globally competitive market. Estimating product costs more accurately have become a strategic objective. The recent development of the activity-based costing (ABC) system methodology has helped company managers to estimate product costs more accurately. Moreover, green competitiveness will be a critical factor to support companies' sustainable development. With today's situation in mind, where a number of stakeholders have begun to focus on companies' environmental activities, a well performed environmental accounting could be a very valuable management communication tool. More firms put increasing emphasis on environmental cost accounting (ECA) system because the costs of complying with environmental regulation (WEEE, RoHS and EuP) have increased. The impact of regulation on the cost of production is expected to become an important determinant for the international competitiveness of firms. In response to cost pressures, many companies have launched a number of initiatives aimed at improving efficiency and reducing environmental impact; as a result, integrated ABC and ECA system must be developed to achieve goals of sustainable competitive advantage. How to integrate these two methods motivates this study. Therefore, the purpose of this study is to propose an appropriate approach to integrate ABC and ECA systems.

This paper presents an overall strategy of integrating ABC and ECA systems to gives readers ideas where they can utilise to implement in their own company. The focus is that the ABC system can help a company better understanding its environmental costs. At the same time, a detailed case study analysing process is used here to illustrate the comparison between the traditional cost accounting system and the ABC system for allocating environmental costs. The company, in this case, has successfully established an ECA system but has not yet integrated it with the ABC system. Our study is presented in the hope of contributing to the integrated ABC–ECA system to enhance the company's capacity to address the challenge of sustainable development more effectively.

The rest of this paper is organised as follows: in Section 2, we introduce the basic concepts of ABC and ECA systems. In Section 3, we discuss the integrated ABC–ECA system in more details. In Section 4, we illustrate this integrated system with a case study. Section 5 concludes this paper with some general guidelines and recommendations to managers. And finally, Section 6 discusses the limitations and future research directions.

2 Concepts of ABC and ECA systems

2.1 The ABC system

Traditional product cost accounting systems have been based on specific direct cost categories such as labour and materials, plus a residual indirect cost called overhead that is either being allocated to products on a more or less arbitrary basis, or written off as a period cost (expense), and therefore not tracked through products at all (Bennett and James, 1997). ABC system, developed in practice and reported by Cooper and Kaplan (1988), is seen as a cost system that accurately assigns overhead costs to products. It examines activities that are actually relevant to the production of a product and attempts to determine which products are profitable, which customers are the most valuable, whether processes are value-added or not and where efforts towards improvement should be made (Gupta and Galloway, 2003). According to Cooper and Kaplan (1988), the ABC system removes distortions from the traditional cost accounting system and provides more representative costing measurements for better decision making. In fact, ABC system has been called one of the most important management innovations the last hundred years (Emblemsvåg, 2000). It is an approach to cost management that moves management focus beyond the traditional emphasis of short-term planning, control and decision making, and product costing to a more integrated, strategic, competition-sensitive way of looking at internal cost structures (White et al., 1995).

Currently, ABC system has become an important tool to improve competitiveness in business organisations as attempts are being made to adopt new ways of allocating overhead costs while calculating the costs of products or any other cost objects. The use of ABC system in accounting activities is not new. Accountants are normally familiar with this ABC system (ECOLIFE II, 2003). Many companies have successfully used the ABC system to change their pricing scheme or to better allocate their resources. The benefits of a well-structured ABC system extend beyond having a more accurate understanding of costs. Because ABC system focuses attention on the activities that are required to achieve business objectives, it encourages managers to improve the efficiency of activities and to reduce or eliminate activities that do not add value (NEWMOA, 1998). Through the diffusion of ABC/management (Askarany et al., 2007), the information obtained from the ABC system has been utilised for product pricing, sourcing, new product development, product profitability analysis (Goebel et al., 1998), product-mix decision (Tsai, 1994; Tsai et al., 2008), customer profitability analysis (Noone and Griffin, 1999), cost of quality analysis (Tsai, 1998), joint products decision (Tsai, 1996b; Tsai et al., 2008), environmental management (Tsai and Hung, 2009a,b;

Tsai et al., 2007a), project management (Raz and Elnathan, 1999), software development (Fichman and Kemerer, 2002) and so on.

The ABC system focuses on the accurate cost assignment of overhead costs to products. The assignment of costs through ABC system occurs in two stages: activities consume resource costs and cost objects (i.e. products or services) consume activities. In practice, this means that resource costs are assigned to various activity centres by using resource drivers in the first stage. An activity centre is composed of a group of related activities, usually defined by function or process. The group of resource drivers is the factor chosen to estimate the consumption of resources by the activities in the activity centres. Every type of resource assigned to an activity centre becomes a cost element in an activity cost pool. In addition, in the second stage, each activity cost pool is traced to the cost objects via an activity driver that measures activity consumption by cost objects (Turney, 2005). Then, the total cost of a specific product can be calculated by adding the costs of various activities assigned to the product.

Cooper (1990) classified the activities into four general categories for manufacturing activities. The four categories of activities are:

1. unit-level, performed each time a unit is produced, for example, ordering dishes
2. batch-level, performed each time a batch of goods is produced, for example, resupplying
3. product-level, performed as needed to support all units of a particular product, for example, purchasing parts or components
4. facility-level, performed to sustain the firm's performance, for example, rent, depreciation, administrative operation, etc.

The costs of different levels of activities will be assigned to products by using different kinds of activity drivers. For example, 'number of machine hours' is used for the activity 'machining', 'set-up hours' for 'machine set-up', and 'number of design hours' for 'product design' (Tsai, 1996b). In the service sectors, there are also examples as 'number of enquiries' for the 'reference desk enquiries' activity or 'number of catalogued items' for the 'database maintenance' activity in the library (Ellis-Newman and Robinson, 1998). Some costs can be directly linked through a causal chain, while many costs can be indirectly linked to a cost object. Costs that can be directly linked to products are said to be traced to the cost object, while indirect costs have to be allocated to the cost object because there is no direct causal reason for making the link (Burritt, 1997). Frequently, the costs of facility-level activities cannot be traced to products with the definite cause–effect relationship and should be traced to products with proper allocation basis (Cooper, 1990).

In short, ABC system allocates resources to activities, and then activities to cost objects, through imputed causal relations based upon volume and non-volume-related drivers (Cooper, 1990). However, this does not guarantee that indirect costs are correctly attributed to products (Armstrong, 2002; Jones and Dugdale, 2002). Several reservations have been expressed regarding the efficacy of ABC system (Innes et al., 2000; Major and Hopper, 2005; Malmi, 1997). In some cases firms have failed to complete their ABC projects and in others they have failed to gain benefits expected from the ABC system they have installed (Lyne and Friedman, 1996). Generally, it is accepted that there is no universally appropriate accounting system suitable to all organisations in all circumstances (Emmanuel et al., 1990). The precision of an ABC system depends upon the level of details of its operation information. An appropriate choice of this detail level is crucial. Tsai (1996a) suggested using work sampling to estimate the percentage of the indirect worker time to overcome this drawback. The work sampling is particularly helpful in the analysis of non-repetitive or irregularly occurring activities.

2.2 The ECA system

Environmental costs are traditionally lumped into overhead/administrative accounts, and because of their less tangible and difficult-to-quantify nature, environmental costs are particularly susceptible to disconnection from the products, processes or activities, responsible for their creation. The environmental costs are greatly underestimated over the past two decades, and most of these costs are usually not traced systematically and attributed to the responsible processes and products. Yet, they are simply summed up in general overheads. There are numerous examples of potentially important environment-related costs being inadvertently hidden in the accounting records, where a manager who would like to benefit from that information cannot find it easily (Jasch and Savage, 2005). For instance, according to the Amoco Yorktown Refinery case study, documented in 'Green Ledgers: Case Studies in Corporate Environmental Accounting', a large sample of employees estimated environmental costs to be 3% of non-crude operating expenses. After further investigation, those costs were found to be at least 22% of non-crude operating costs (Ditz et al., 1995). Kreuze and Newell (1994) observed that the arbitrary cost allocation leads to the incorrect accumulation of product costs. As a result, when environmental costs are not separately recognised but aggregated in a common overhead pool and then allocated to products, those products that actually have lower environmental costs provide the products with higher environmental costs with a cross-subsidy. The 'dirty' products are sold too cheaply whereas the products that are relatively more environmentally benign are sold too expensively. Therefore, wrong pricing decisions could reduce a company's competitiveness.

The company AT&T in the USA performed a study of the environmental accounting (in their vocabulary under the name 'Green Accounting') in 1995, and they stated that: "... the best business focus for Green Accounting is the collection and use of information for internal management, because making better decisions will result in improved performance for external reporting" (US EPA, 1995b).

In general, the environmental accounting describes, measures, and reports on the allocation of environmental resources, costs, expenditures and risks to various industry groups, to specific firms, or within firms to specific departments, projects, activities or processes (Gale and Stokoe, 2001). An advanced step of the development of an environmental accounting is the development of the ECA. It directly places a cost on every environmental aspect, and determines the cost of all types of related environmental actions. Environmental actions include pollution prevention, environmental design and environmental management (Yakhou and Dorweiler, 2004). The main problem of ECA system is that we lack a standard definition of environmental costs. Depending on various interests, environmental costs include a variety of costs (Jasch, 2003).

The US Environmental Protection Agency (US EPA) identifies a hierarchy of environmental costs linked to the pollution prevention (US EPA, 1995a). These include:

1 direct environmental costs associated with the preventing pollution
2 hidden costs of the environmental regulation
3 contingent liabilities arising from the need to remediate contaminated sites, and penalties for non-compliance with legislation and regulations
4 intangible costs and benefits of the pollution prevention associated with stakeholder attitudes and the perceptions of the organisation.

Quarles (1995) examined the critical issues related to the identification and classification of environmental expenditures by business organisations. The developed EPA environmental cost classification scheme was reviewed, and a number of potential shortcomings of that system were identified. This study proposed an alternative environmental cost classification system based on the concepts of ABC. This ABC system has overcome many of the potential shortcomings of the US EPA system and could be more useful for internal management decision making, regarding the nature and extent of environmental expenditures. The five categories of environmental costs are preventive costs, detective costs, corrective costs, disposal costs and reporting costs.

Ministry of environment promoted a research to develop announcement factors and methods of environmental information applicable to enterprises in Korea. This guideline was pursuant to the cost classification by the environmental activity of an enterprise, and the subsequently environmental-related cost was classified in four factors as below (KMOE, 2003).

1 pollution treatment activities
2 pollution prevention activities
3 stakeholder activity
4 environmental compliance and remediation activities.

Japan's Ministry of the environment pointed out environmental accounting aims at achieving sustainable development, maintaining a favourable relationship with the community and pursuing effective environmental conservation activities. These accounting procedures allow a company to identify the cost of environmental conservation during the normal course of business, to recognise benefits gained from such activities, to provide the best possible means of quantitative measurement (in monetary value or physical units), and to support the communication of its results (JMOE, 2005). Each environmental cost is categorised according to the relevant business activities. Key business activities span the range of goods, purchasing through production and distribution. Administrative activities, R&D and social activities are considered separate categories in the series of business activities through sales. And environmental costs are described as below.

1 business area cost
2 upstream/downstream costs
3 administration cost

4 R&D cost

5 social activity cost

6 environmental remediation cost.

The life cycle of a generic industrial product was defined by SETAC (1991) as being composed of raw material acquisition, processed/manufactured, distributed/transported, used/reused/maintained, recycled and managed as waste. Senthil et al. (2003) proposed life cycle environmental cost (LCEC) analysis model, which is to include the eco-costs of a product into the total cost of the product. The newly developed categories of eco-costs are: costs of effluent treatment/control/disposal, environmental management systems, eco-taxes, rehabilitation and energy savings of recycling and reuse strategies.

To summarise, there are various approaches in connection with categorisation of environmental costs. In Japanese version, environmental costs are categorised according to all life cycle activities of a product. These costs are called 'LCECs'. LCEC model takes into consideration all aspects of product life cycle, thus it provides a more comprehensive approach to analyse environmental costs.

3 Integrating ABC and ECA systems

The main part of environment-related costs, such as energy, water, waste disposal and the salaries of environmental staffs are likely to be included in overheads (White and Savage, 1995; White et al., 1995). These practices indicate that, where products or processes have high environmental costs, the figures can be hidden from decision-makers. This diminishes the motivation to reduce the costs and can also create a bias against pollution prevention projects (White et al., 1995). An approach that is of particular relevance to environment is the ABC. It tries to create more meaningful cost information by tracking costs to products and activities on the basis of the underlying 'drivers' that cause those costs to be created in the first place. The amount of costs lost in overheads is thereby greatly reduced. As a result, product prices can be set more accurately, and significant cost drivers can be targeted for cost reduction measures. Where environment is a significant cost driver, it will be highlighted naturally by ABC activities (Bennett and James, 1998). Furthermore, Brooks et al. (1993) proposed that, by incorporating environmental costs into the ABC system, organisations can more accurately identify those products and plants that are driving their environmental costs. Once identified, firms would then be better equipped to determine which products to eliminate, which materials to change and what processes to modify. AT&T has pointed out that its Green Accounting should be based on activity-based management and ABC principles, and the company should set up a 'baseline' of information about the degree to which environmental costs can be allocated to specific products (Parker, 2000). Therefore, ABC system improves the product cost calculations by allocating costs, typically found in overhead accounts to the polluting activities and products, determined by quantitative life cycle assessment procedures (Beer and Friend, 2006).

If environmental costs are treated as overhead costs to be allocated, this will reduce the transparency of environmental costs; it is important for the environmental cost management. It will also result in distorted costs for the decision making if no specific mechanism to link the environmental costs to products is defined. In consequence, companies need to incorporate environmental impacts and costs into the product costing and pricing by integrating ABC and ECA systems.

Previous studies have various problems in terms of classification of environmental costs and selection of cost drivers. Some did not make use of cost drivers (Brooks et al., 1993), some had rough and inadequate cost drivers (Quarles and Stratton, 1998; Rogers and Kristof, 2003; Schaltegger and Müller, 1997; Stuart et al., 1996), some categorised environmental activities too arbitrary (Quarles and Stratton, 1998; Stuart et al., 1996) and some allocated environmental costs without identifying environmental activities (Brooks et al., 1993; Rogers and Kristof, 2003; Schaltegger and Müller, 1997). This paper attempts to overcome the weaknesses of previous studies by using more appropriate cost drivers and more complete environmental activities to allocate environmental costs.

Firstly, to determine indirect environmental costs, one must identify resources consumed, environmental activities and causal relationships between the environmental activities and the resources used to perform them. Once this is completed, environmental activity costs can then be assigned to the product or process. The identification of associated activities provides the link between what is actually occurring within the company, and costs from the associated resources required for those activities. Each activity will require different resources (e.g. labour, material, utility, etc.) including a range of associated resource costs. By recognising the activity's pattern of resource used and selecting the most appropriate measure of the resources consumed (known as resource drivers); a company can begin to allocate proper resource costs to each activity. These are subsequently linked to cost objects by discovering the relevant activity pattern for each cost object and choosing the most appropriate measure of the level of activity (known as activity drivers). The proposed environmental activities and activity drivers are depicted in Table 1. The appropriate selection of environmental activities and activity drivers through the ABC system allow companies to trace many environmental overhead costs to cost objects and may give company management a better overview of environmental costs. For example, factory maintenance or cleaning costs can be segmented according to the different activities. Maintenance costs of environmental components, such as 'clean-up of spills' or 'collection and separation of recyclable materials' can be identified and measured. In contrast, traditional cost accounting system ignores the activity stage and at best allocates resource costs directly to cost objects based on the crude drivers such as direct labour hours and machine hours.

The following steps are performed to identify and estimate an appropriate cost of each environmental activity associated with the product (cf. Ben-Arieh and Qian, 2003):

Step 1 Identify resources (i.e. what is used to do work).

Step 2 Analyse resource driver rates.

Step 3 Identify environmental activities.

Step 4 Assign resources to each environmental activity via resource drivers spent.

Step 5 Analyse the environmental cost for each activity.

Step 6 Define activity drivers for each activity and find its activity driver rate.

Step 7 Calculate the total environmental cost for each product via activity drivers spent.

In the next section, a case study is illustrated to demonstrate this integrated ABC–ECA system for allocating environmental costs to products and compare the results of the traditional cost accounting system and the ABC system.

Table 1 Resources and activity drivers for environmental activities

Activity centre	*Environmental activity*	*Resources*	*Activity driver (physical unit)*
Pollution prevention activity centre	1 Air pollution prevention activity (including acid rain)	Equipment, labour, utility	Volume of waste emissions (kg)
	2 Water pollution prevention activity	Equipment, labour, utility	Volume of waste water (m^3)
	3 Ground contamination prevention activity	Equipment, labour, utility	Volume of contaminated ground (m^2)
	4 Noise pollution prevention activity	Equipment, labour, utility	Noise (decibels)
	5 Vibration pollution prevention activity	Equipment, labour, utility	Vibration (decibels)
	6 Odour pollution prevention activity	Equipment, labour, utility	Volume of foul odour (mg/l)
	7 Ground sink down prevention activity	Equipment, labour, utility	Volume of pumped water (m^3)
	8 Other types of pollution prevention activity	Equipment, labour, utility	Volume of NO_X, $SO_{X,}$ emissions (tons)
Global environmental conservation activity centre	1 Global warming and energy conservation prevention activity	Equipment, labour, utility	Volume of greenhouse gas emissions (tons-CO_2)
	2 The ozone depletion prevention activity	Equipment, labour, utility	Volume of greenhouse gas emissions (tons-CO_2)
	3 Other global environmental conservation activities	Equipment, labour, utility	Volume of greenhouse gas emissions (tons-CO_2)
Resource recycling activity centre	1 Activity for the efficient utilisation of resources	Equipment, labour, utility	Total energy input volume (joules) Water input volume (m^3)
	2 Activity for recycling industrial waste	Equipment, labour, utility	Volume of recycled industrial waste (tons)
	3 Activity for recycling hazardous waste	Equipment, labour, utility	Volume of recycled hazardous waste (tons)
	4 Activity for disposal of industrial waste	Equipment, labour, utility	Volume of non-recycled industrial waste (tons)
	5 Activity for disposal of hazardous waste	Equipment, labour, utility	Volume of non-recycled hazardous waste (tons)
	6 Activity contributing to resource circulation	Equipment, labour, utility	Input volume of circulated resources (tons)

Table 1 Resources and activity drivers for environmental activities (continued)

Activity centre	*Environmental activity*	*Resources*	*Activity driver (physical unit)*
Upstream/ downstream activity centre	1 Green purchasing and typical goods and services procurement and purchasing methods	Labour, material	Number of purchasing (no.)
	2 Additional activity for supplying environmentally conscious products	Labour	Volume of toxics (tons)
	3 Additional activity for reducing the environmental impact of containers and packaging	Labour	Volume of containers and packaging used (tons)
	4 Activity for the collection, recycling, resale and proper disposal of used products	Labour	Volume of products circulated, such as products, containers and packaging collected after use (tons)
Administration activity centre	1 Activity for the implementation and maintenance of an environmental management system	Labour	Time EHSD[a] spends supporting each business unit (hr)
	2 Activity for disclosure of environmental information associated with business activities and environmental advertising	Labour	Time EHSD[a] spends supporting each business unit (hr)
	3 Activity for monitoring environmental impact	Labour	Number of internal audit (no.)
	4 Activity for environmental training of employees	Labour, material	Number of trained employees Time of training sessions (hr)
	5 Activity for environmental improvement activities, such as nature conservation, greening, beautification and landscape preservation, at or in the vicinity of the business site	Labour	Distribute proportionally to all business units based on revenue (dollars)
R&D activity centre	1 R&D activity to develop products that contribute to environmental conservation	Labour, material	Time of R&D (hr)
	2 R&D activity to curtail environmental impact at the product manufacturing stage	Labour, material	Time of R&D (hr)
	3 Other R&D activity associated to the curtailment of environmental impact at the distribution stage or the marketing stage of products	Labour, material	Time of R&D (hr)

Table 1 Resources and activity drivers for environmental activities (continued)

Activity centre	*Environmental activity*	*Resources*	*Activity driver (physical unit)*
Social activity centre	1 Activity for environmental improvement activities, including nature conservation, planting of greenery, beautification and landscape preservation, with the exception of the business site	None	Distribute proportionally to all business units based on space (m^2)
	2 Activity related to donation or financial support of environmental groups	None	Distribute proportionally to all business units based on revenue (dollars)
	3 Activity associated with various social activities, such as the financial support of a local community's environmental conservation activities and the disclosure of information to the local community	None	Distribute proportionally to all business units based on revenue (dollars)
Environmental remediation activity centre	1 Activity to restore the natural environment back to its original state	Labour, material	Volume of contaminated ground (m^2) Volume of waste water (m^3)
	2 Activity to cover degradation suits connected with environmental conservation	Labour	Volume of waste emissions (tons)
	3 Provisions or insurance fees to cover degradation to the environment	None	Number of incidents (no.)

[a]EHSD stands for Environmental, Health and Safety Department.

4 Case study of a DRAM manufacturer

4.1 Environmental management of the company

XYZ Company, founded at the Hsinchu Science Park in December 1994, is a well-known DRAM manufacturer in the world and the largest domestic computer memory company in Taiwan. The company focuses primarily on DRAM products for standard memory applications and foundry service products. The manufacturing process of DRAM is complicated and intricate. It must take place in a dust-free environment. After the front-end process of photolithography, diffusion, implantation and etching, each individual chip of the wafer is then tested and packaged to become the final IC product.

The semiconductor industry is highly polluted. With rapid growth in the electronics and computer sectors, environmental and health issues associated with semiconductor manufacturing are growing in significance. Hence, XYZ Company has continued to work towards resource recycling and pollution prevention since last year. The wafer fabrication process generates gaseous, liquid and solid chemical wastes. Typically, gaseous wastes consist of nitrogen hydride, acid vapour, volatile organic compound and certain minor toxic gases. Typically, liquid wastes consist of acidic or alkaline liquid water, hydrogen fluoride and other waste water. Typically, solid wastes consist of calcium fluoride sludge, resulting from the treatment of certain liquid wastes, scraps and certain non-toxic industrial wastes. In the air pollution management, XYZ Company has completed the construction of an acid and volatile organic exhausting backup prevention equipment to minimise the environmental impact from malfunctioning of the pollution prevention equipment. Gaseous wastes are treated in scrubbers before they are discharged into the open air. XYZ Company neutralises acidic or alkaline liquid wastes and treats other types of liquid wastes by precipitation before releasing the treated water into the central liquid waste treatment plant operated by the Hsinchu Science Park Administration for final treatment. In the area of energy and resource conservation, XYZ Company has been continuously improving the efficiency of power usage as well as maintaining the ratio of recycled water above 85%. In the area of waste management, XYZ Company has improved and increased not only the quantity and varieties of recycled wastes, but also recycled solvents and calcium fluoride sludge discharged from the factory for reuse by the cement industry. On the other hand, the company has retained waste disposal contractors, which have been licensed by the Hsinchu Municipal Environment Protection Agency, for collecting, removing and storing the solid wastes.

XYZ Company is subject to a variety of regulations, relating to the usage, storage, discharge and disposal of chemicals and gases used in manufacturing process by the Hsinchu Science Park Administration, the Hsinchu municipal environmental protection administrative agency, as well as the national environmental protection agency. From time-to-time, the Hsinchu municipal environmental protection administrative agency conducts unannounced random inspections at the fabrication facility to monitor compliance with the applicable environmental protection laws and regulations. To ensure compliance with the applicable environmental protection laws and regulations, XYZ Company regularly monitors and inspects discharged wastes and audits the performance of waste treatment both for the manufactories and contractors. XYZ Company has not suffered material environmental claims in the past and has been certified as ISO 14001 compliant. Acknowledging the company's responsibility towards overall environmental maintenance and maintaining a harmonious relationship with the local community, the quality of water discharged, exhaust, surrounding air quality and noise levels are tracked and recorded regularly to gain an understanding of the operation's impact on the surrounding environment.

XYZ Company has received several awards from the Taiwan government for the excellent performance in the environmental protection. In October 1998, its environmental protection management system was certified to meet the ISO 14001 environmental protection standard, which was recertified in October 2004 per ISO regulations. To achieve appropriate environmental health and safety management, XYZ Company established the environmental health and safety management system in 2002 and obtained the OHSAS 18001 certification in the same year. XYZ Company has adopted adequate antipollution measures for the effective maintenance of environmental protection standards that are consistent with the practice of the semiconductor industry in Taiwan. XYZ Company is also in compliance in all material respects with applicable environmental laws and regulations.

4.2 Establishment of the ECA system

Pursuing the policy of sustainable management to raise the company's competitive edge, XYZ Company has started to collect, comprehend information and gather data related to ECA system since 2002. However, the company could not grasp an in-depth understanding of the situation, especially for the environmental protection-related costs incurred by on-site departments because these costs could not be systematically categorised to perform statistical analyses.

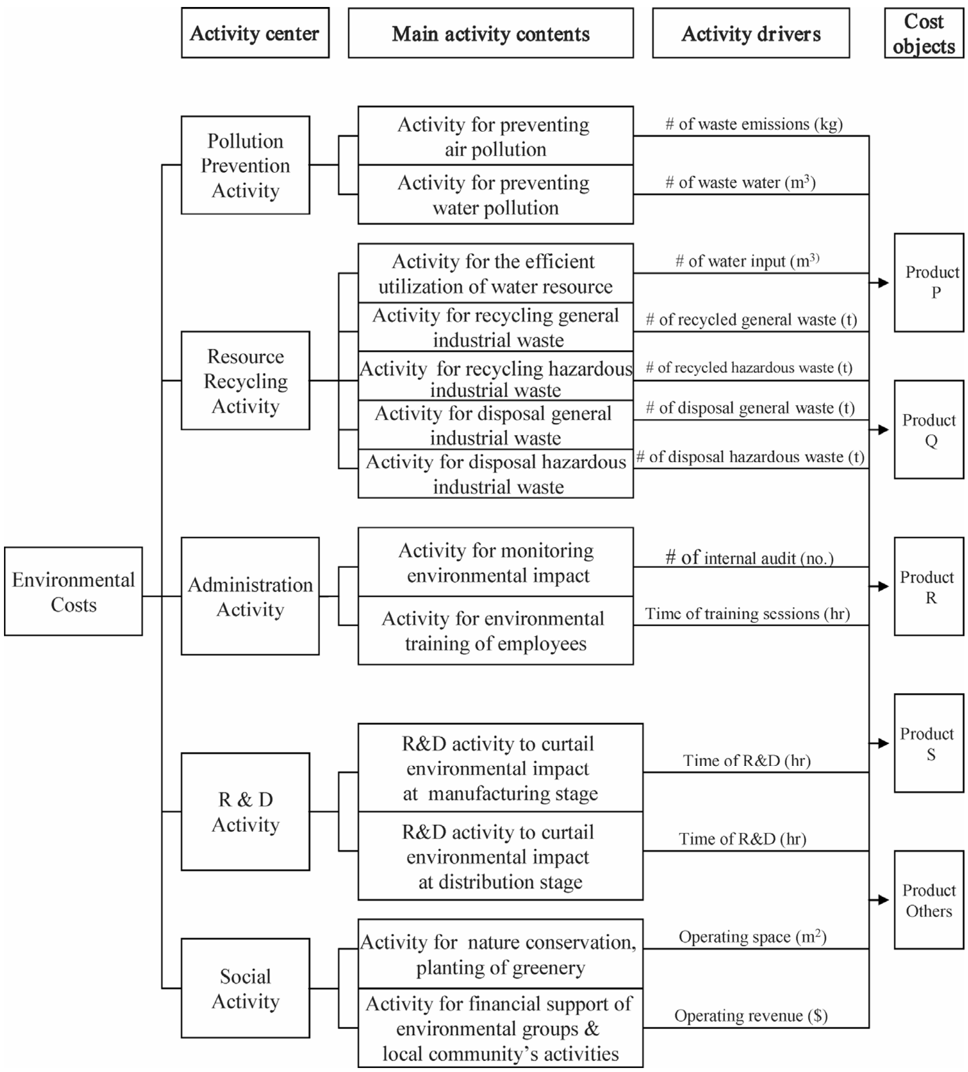
Fortunately, the Ministry of Economic Affairs Industrial Development Bureau (IDB) provided with the technical and financial support in 2003. Based on the guidance of the structure of 'ECA system', provided by IDB, XYZ Company initiated in-plant accounting information system programmes in 2004, completed functional modifications in August, proceeded with on-line training and operated the system in October officially. The ECA system combines current cost accounting systems, and uses pattern comparison and an internal coding method to calculate XYZ Company's invested costs and expenditures on the environmental protection. This helps the company conduct overall evaluations for the environmental benefit and carry out decision-making analyses. Unlike the general ECA system, the ECA system not only includes costs of environmental pollution prevention and control activity but also comprises costs of safety, sanitation and fire prevention. Thus, it presents sufficient and detailed information. Because Taiwan's Environmental Protection Administration (TEPA) provided guideline of Japanese version to many industries, XYZ Company, as well as 31 companies in Taiwan, has successfully built environmental accounting system to categorise environmental costs by applying Japanese version till now. But external environmental cost is difficult to estimate, the company dose not internalise it yet.

4.3 Integrating ABC and ECA systems

Currently, XYZ Company has established the ECA system, but the company has not allocated environmental costs through the ABC system to each product yet. This is a crucial problem because incorrect cost allocation can distort corporate decision-making. It may be appropriate for an ABC system to be adopted as in the process it could turn many manufacturing overhead costs related to the environment into direct costs.

In this case, we review XYZ Company's 2004 year-end financial report and corporate environmental report, supporting documentation and cost driver survey, and consult with managers and staff at Environmental, Health and Safety Department. Details of this study are confined to the fiscal year 2004. The company produces seven products (except foundry service products) of product P, Q, R, S and others (that combine three products because of low-volume). In its traditional cost accounting system, overhead costs are allocated to each product using machine hours. Because product P, Q, R, S and others consume various machine resources, environmental costs are allocated by the percentage of consumptions. Nevertheless, in the new ABC system, we identify five activities centres, namely the pollution prevention centre, the resource recycling centre, the administration centre, the R&D centre and the social centre. Each activity centre is composed of related activities. In the first stage, environmental costs are assigned by resource drivers to activities which are classified into the five activities centres. Then, in the second stage, the five activity centre costs are distributed to the five products by activity volume consumed. Figure 1 shows the detailed environmental cost assignment view of the ABC system. It includes activity centres, main activity contents, activity drivers and cost objects. The activities for preventing air pollution vary with the volume of waste emission by each of these products. The activities for monitoring environmental impact vary with the number of internal audit by each of these products, and so forth. All of those activities are categorised into the five activities centres based on their functionalities.

Figure 1 ABC system for environmental costs



We obtain Table 2 after applying seven-step procedures mentioned in previous section. Because the company has not implemented the ABC system, this table is derived from its existing data assuming the ABC system is used and these numbers are slightly adjusted to protect the company confidentiality. Table 2 shows the analysis for activities and the assignment of activities for products by activity drivers. Resource costs are traced to activities as shown in column (1) of this table. Columns (2)–(8) present a detail about how activities are allocated to each product by activity drivers. For example, the first line indicates how environmental costs of each of those activities are assigned to the five cost objects, based on the quantity of kilograms of waste emission by each in proportion to total emissions. The volume of waste emissions is 6,917 kg. The driver is executed to trace the air pollution prevention activity to the five products separately, and 5,395.26, 207.51, 276.68, 415.02 and 622.53 kg of waste emissions are assigning, respectively. As shown in Columns (9)–(13), NT$2,072,538 of the cost of the air pollution prevention is assigned to product P, NT$79,713 to product Q, NT$106,284 to product R, NT$159,426 to product S and NT$239,139 to other products. The environmental cost for each individual activity is assigned to the cost objects in the same manner. Finally, adding all allocated activity costs in each product, we can get the total activity costs. By following these steps for all of the environmental activities, the total cost for each activity centre can be determined for each cost object.

4.4 Discussion

The importance of implementing the ABC system to allocate costs to products has illustrated in Table 2, which presents the environmental costs for the XYZ Company, using the traditional cost accounting system based on the single cost driver machine hour method and the ABC system based on several more accurate activities and cost drivers. For the traditional cost accounting method, the environmental costs for product P, Q, R, S and others are NT$24,366,867, NT$1,001,378, NT$1,184,964, NT$1,610,550 and NT$91,793, respectively. Product P, with machine hours as an allocation base (cost driver), receives more overhead costs than under the ABC system. Conversely, Product Q, R, S and others are allocated fewer overhead costs by using machine hours as the allocation base (cost driver).

It is worth noting that the areas where the improvement is needed can be identified through the categorisation of activities as ‘value-added’ or ‘non-value-added’. The designation ‘non-value-added’ reflects a belief that the activity can be redesigned, reduced or eliminated without reducing the quantity, responsiveness or quality of the output required by the customer or the organisation. The attribute ‘value-added’ reflects a belief that the activity cannot be eliminated without reducing the quantity, responsiveness or quality of output required by a customer or organisation (Beheshti, 2004). For the non-value-added activities such as pollution control activity and environmental compliance, improvement initiatives should be directed towards eliminating or minimising the activities. For the valued-added activities such as pollution prevention activity, improvement initiatives should be directed towards streamlining, improving what is being done and optimising performance (Miller, 1996). This paper defines the disposal general industrial waste, disposal hazardous industrial waste and monitor environmental impact as the non-value-added activities. The proportion of the three activities is 12.85% ($3,631,160/$28,255,552) of total environmental costs, which provides opportunities for improvement. The proportion of disposal general and hazardous industrial waste is 11.93% ($3,370,000/$28,255,552) of total environmental costs, which provides improvable opportunities for minimising wastes.

Table 2 Comparing ABC with traditional cost accounting

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
ABC allocation:		*Quantities of drivers*						*Unit cost per activity driver**	*Life cycle environmental cost**				
Environmental activity	*Total cost**	*P*	*Q*	*R*	*S*	*Others*	*Total quantity*		*P*	*Q*	*R*	*S*	*Others*
Activity for preventing air pollution	$2,657,100	5,395.26	207.51	276.68	415.02	622.53	6,917.00	$384.14	$2,072,538	$79,713	$106,284	$159,426	$239,139
Activity for preventing water pollution	2,869,640	1,381,066.88	133,114.88	99,836.16	33,278.72	16,639.36	1,663,936.00	1.72	2,381,801	229,571	172,178	57,393	28,696
Activity for the efficient utilisation of water resource	544,400	3,826,004.00	92,496.80	42,044.00	84,088.00	159,767.20	4,204,400.00	0.13	495,404	11,977	5,444	10,888	20,687
Activity for recycling general industrial waste	528,590	2,584.30	90.15	120.20	180.30	30.05	3,005.00	175.90	454,587	15,858	21,144	31,715	5,286
Activity for recycling hazardous industrial waste	2,304,990	1,027.62	202.41	217.98	93.42	15.57	1,557.00	1,480.40	1,521,293	299,649	322,699	138,299	23,050
Activity for disposal of general industrial waste	2,051,100	1,406.72	577.76	100.48	150.72	276.32	2,512.00	816.52	1,148,616	471,753	82,044	123,066	225,621

Table 2 Comparing ABC with traditional cost accounting (continued)

	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*	*(13)*
ABC allocation:		*Quantities of drivers*							*Life cycle environ-mental cost**				
Environmental activity	*Total cost**	*P*	*Q*	*R*	*S*	*Others*	*Total quantity*	*Unit cost per activity driver**	*P*	*Q*	*R*	*S*	*Others*
Activity for disposal of hazardous industrial waste	1,318,900	962.74	39.03	52.04	78.06	169.13	1,301.00	1,013.76	975,986	39,567	52,756	79,134	171,457
Activity for monitoring environmental impact	261,160	671.46	140.79	43.32	64.98	162.45	1,083.00	241.14	161,919	33,951	10,446	15,670	39,174
Activity for environmental training of employees	887,925	210.70	7.35	9.80	14.70	2.45	245.00	3,624.18	763,616	26,638	35,517	53,276	8,879
R&D activity to curtail environmental impact at the manufacturing stage	4,653,462	22,400.00	20,000.00	16,000.00	14,400.00	7,200.00	80,000.00	58.17	1,302,969	1,163,366	930,692	837,623	418,812
R&D activity to curtail of environmental impact at distribution stage	2,573,860	15,600.00	13,800.00	7,800.00	9,600.00	13,200.00	60,000.00	42.90	669,204	591,988	334,602	411,818	566,249

Table 2 Comparing ABC with traditional cost accounting (continued)

	(1)	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*	*(13)*
ABC allocation:		*Quantities of drivers*						*Unit cost per activity driver**	*Life cycle environmental cost**				
Environmental activity	*Total cost**	*P*	*Q*	*R*	*S*	*Others*	*Total quantity*		*P*	*Q*	*R*	*S*	*Others*
Activity for nature conservation, planting of greenery	684,925	38,528.00	1,344.00	1,792.00	1,792.00	1,344.00	44,800.00	15.29	589,036	20,548	27,397	27,397	20,548
Activity for financial support of environmental groups and local community's activities	6,919,500	28,772.10	1,101.00	1,445.60	1,936.30	107.50	33,362.50	207.40	5,967,435	228,351	299,823	401,595	22,296
Total environmental costs (A)	$28,255,552	-	-	-	-	-	-	-	$18,504,404	$3,212,928	$2,401,026	$2,347,300	$1,789,894
Traditional allocation:													
Machine hours	-	665,760	27,360	32,376	44,004	2,508	772,008	-	-	-	-	-	-
Total environmental costs (B)	$28,255,552	-	-	-	-	-	-	-	$24,366,867	$1,001,378	$1,184,964	$1,610,550	$91,793
Difference (B)-(A)	$0	-	-	-	-	-	-	-	$5,862,463	($2,211,550)	($1,216,062)	($736,750)	($1,698,101)

*Unit: NT$

As above, environmental costs related to certain products can cause the traditional cost accounting allocation method of machine hours to produce faulty product costs. This might, however, be an incorrect way to allocate some typical environment-related costs. An instance can be hazardous waste disposal costs, which might be high for one product that uses hazardous materials and low for the other that applies fewer hazardous materials. In this case, the allocation of hazardous waste disposal costs on the basis of machine hours would be inaccurate. If managers depend on the wrong product cost information to make product pricing and other decisions, it will reduce the company's green competitiveness. In fact, product-specific environmental costs for many companies may require the employment of the ABC system. Although, the ABC system does not warrant that environmental costs are correctly attributed to products – estimation and approximation by nature, it is more accurate than the traditional method.

Therefore, the link between ABC and ECA systems will be exploited as the base for a quantitative evaluation of the cost effectiveness of tasks for managing environment. The results will enable managers to understand the financial information regarding the activities for environmental protection and the percentage of environmental costs in the overall product costs. Furthermore, managers can use the information as bases for making more objective decisions. As a result of this case study, the company's managers have understood it is beneficial and important to integrate ABC and ECA systems, but currently there is no budget and manpower for this project. Effective implementation of the ABC system is often linked to behavioural rather than technical factors (Shields, 1995). In the future, if the company has adequate resources for implementing this integrating ABC–ECA system, it is necessary to gain employees' support and reduce their resistance.

5 Conclusions

ABC is a promising approach to remedy the 'black box' nature of overheads (Bartolomeo et al., 2000). This paper shows how the traditional cost accounting method produces inaccurate costs and that the ABC system is more practical and suitable for the allocation of environmental costs. The major contribution of this paper is to help managers understand how to allocate environmental costs to each product more accurately through appropriate cost drivers.

ABC technique can provide the means to identify cost bearing activities effectively and to allocate costs to individual products on a fairer basis. Costs are allocated to products on the basis of the individual's demand for activities. If costs are not allocated to appropriate cost objects, company managers may make wrong resource allocation, product-mix and product-pricing decisions. In addition, the ABC system allocates activities among unit-, batch-, product- and facility-level activity. Environmental expenditures can occur in any of these levels and life cycles. The consideration of all costs of life cycle, from the introduction phases to product maturity, that is, its cradle to grave, can allow for the development of better designing methods, production methodologies, marketing strategies and disposal options. Environmental costs are presented at every level of the life cycle. If they are not taken into account and allocated per activity, they will result in wrong costing of products. The ABC system can provide management with accurate product cost information and therefore, a realistic understanding of profitability is delivered. Relevant product cost information permits management accountants to identify the costs associated with non-value-added activities. Furthermore, by identifying potential contingent environmental liabilities, management accountants can work along with engineers, environmental consultants, engineers, lawyers and others who have relevant information to evaluate the profitability of competing products. Therefore, the combination of ABC and ECA systems will result in a more accurate product cost than the traditional cost accounting methods.

Exercises in 'green accounting' are seen as being part of the construction of indicators of sustainability (Simon, 2000). Therefore, to achieve the goal of sustainable development, companies need to incorporate environmental impacts and costs into the product costing and pricing by integrating ABC and ECA systems. With the implementation of the ABC system, the causes of environmental costs are better understood, compared with the traditional cost accounting method. It would be recommended that company managers establish the ECA system and allocate environmental costs through the ABC system to products, services and customers to achieve green competitiveness.

Some ERP surveys indicate that many companies have adopted ERP systems to improve their competitiveness, to speed up responses to change, to improve financial management and to simplify access and retrieval of information for strategic planning and operational control (Hsu et al., 2008; Tsai et al., 2007b). Under ERP systems, real-time and integrated information for the activity-based environmental cost analysis can be easily obtained.

6 Limitation

There is at least one limitation to this study, which is worth mentioning. We do not incorporate future costs such as contingent liability costs. However, environmental claims against to, or the company failure to comply with current or future regulations could result in the assessment of damages, imposition of fines against the company, suspension of production or cessation of operations. Any failure to control the use of, or adequately restrict the discharge of, hazardous substances could subject the company to future liabilities. This study does not estimate these environmental liabilities. Future research should incorporate environmental liabilities into the activity-based environmental cost analysis.

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