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Published in:
Waste Management & Research

DOI:
10.1177/0734242X05050184

2005

Appendix 6. Paper VI

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Reprinted from

Waste Management and Research, 2005;23(1), in press,

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Waste Management and Research,

Official Scientific Journal of the ISWA.

Construction Waste Management Based on Industrial Management Models: A Swedish Case Study

Waste Management and Research. 2005;23(1). In press.

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Abstract

This paper describes a methodology for estimating the true internal costs of construction waste, aimed at promoting environmentally friendly waste management. The study employs cost-benefit analysis, contribution margin analysis, the Polluter-Pays Principle and a mathematical model: the model for Efficient Use of Resources for Optimal Production Economy (EUROPE), which has been introduced previously by the author for assigning industrial costs to waste. The calculations are performed on construction waste created in a case study of a building project. Moreover, waste is regarded as, in a business sense, having the same basic status as any normal industrial product, namely the "equality principle". Application of the methodology is suggested to create incentives for environmental and profitability improvement in construction companies and other types of industrial sectors. The results of the case study show the generation of construction waste to substantially decrease the final operating income, due to the internal shadow price cost it creates. This paper is intended to decrease the gap between the choice of waste management procedures and their economic impact, the overall objective being to accomplish an improved industrial environmental situation.

Key words: Construction waste management, industrial economic models, cost-benefit analysis, true internal costs.

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Introduction

One of the greatest problems associated with the European Union environmental policy is the ever-increasing waste generation. The Sixth European Community Environment Action Programme *Environment 2010: Our Future, Our Choice* (EC, 2002) emphasises the need for breaking the relationship between economic growth and increased production of waste. Although large recycling programmes have been implemented, the total waste generation increased by around 15% in Europe between 1995 and 1998 while in the same period the gross domestic product grew by around 10% (Wallström, 2001).

With regard to construction waste management in particular, the situation is generally equally alarming. In Stockholm, the capital of Sweden, the construction waste management situation has recently started to get out of control. This is the view of companies in the construction industry who say that the severe problems may lead to the occurrence of illegal dumping due to, for example, excessive taxation of (construction) waste (Appelgren, 2001).

Waste generated from construction and demolition activities specifically, including the renovation of old buildings, accounts for about 32% of all waste generated in Western Europe. The generation of construction and demolition waste in Western Europe generally increased during the 1990s (EEA, 2003).

The overall objective of this study was to contribute to an improvement in societal resource economy. In doing so, a theoretical description and evaluation has been made of certain common business economic models that have been applied to construction waste management through case studies.

Methodology

In an industrial management models section, methods that are commonly used for estimating product costs are considered, together with ways in which these methods can be adjusted for use in estimating the true internal costs of construction waste fractionation. The construction waste management case study that follows gives the facts and figures for the Block Opus 1 site case study which delivered the material to which the different models have been applied. The source of information to the case study is mainly interviews with the site manager (Ilvemark, personal comm., 2003).

The application of different waste management models to construction waste follows in an analytical section. The formulation of the theory in this section is based on the preceding investigation of the industrial management models and the case study. One corner stone is the applicability of the so called “equality principle”, the equating of industrial waste with normal products in terms of the allocation of revenues and costs, which has been introduced previously (Stenis, 2002). The findings form the scientific basis for the final discussion and conclusions section.

The validity is assured by using generally accepted economic models and by confronting the models with real data from a case study. Good reliability is assured by the same reason.

Industrial management models

Prerequisites for application of the methods studied

When applying a method for industrial waste management, there are different possible scenarios. A particular waste fraction is studied within a given production scenario, involving a set of different waste fractions with which various revenues and costs are associated. The profitability of a given waste fraction is used as an input in assessing waste fraction *shadow prices*. In general terms, a *shadow price* represents the true marginal value of a product or the opportunity cost of a resource, both of which may differ from the market price. The idea of using shadow prices is that if firms were to be charged the shadow price associated with pollution of some type, they would be more alert to adjust their production to keep these prices low. The costs and revenues are estimated in a manner described below.

A new way of looking at waste is needed. Otherwise, the process of achieving environmentally sound industry can be unacceptably slow. A shift in paradigm that is argued for here involves equating industrial waste with normal products in terms of the allocation of revenues and costs, an approach that is termed **the "equality principle"** (Stenis, 2002). This approach forms the basis for the forthcoming discussion. The waste fractions studied are regarded as a company output which is mathematically considered in expression (1) below, used for the allocation of revenues and costs to a certain waste fraction through multiplication by the costs or revenues in question that are to be allocated by splitting them up in their proper proportions.

$$\frac{A}{B + C} \qquad (1)$$

where

A = quantity of a certain waste fraction produced
B = quantity of normal product output
C = sum of the quantities of all the different waste fractions produced

Of course to apply expression (1) a suitable production or administrative unit must be difined, depending on the circumstances. Expression (1) represents the financial implications of the equality principle and is termed *the model for Efficient Use of Resources for Optimal Production Economy (EUROPE).*

In the section below, the methods that are most commonly used for estimating product costs are considered, together with ways in which some of these methods can be adjusted, according to the view of the author, for use in estimating the true internal costs of waste fractionation. The methods are analyzed critically with regard to their suitability for construction waste management. It is demonstrated that not all methods are applicable to all waste management situations. The reviewed methods are given in Table 1.

Table 1. Reviewed methods.

I. Cost-benefit analysis
   1. Method of overhead rates based on normal capacity
   2. Average cost estimation method
   3. Equivalent method of cost estimation
   4. Absorption costing method
   5. Activity Based Costing (ABC) method

II. Contribution margin analysis method

III. The Polluter-Pays Principle (PPP)

Industrial management models and their suitability for construction waste management

Cost benefit analysis

Method of overhead rates based on normal capacity

Mathematically, the problem can be described as follows (Frenckner & Samuelson, 1989):

$$TC = f(x) = FC + VC = FC + k_1 * x, \text{ where } k_1 = (dTC/dx) \quad (2)$$

$$TR = f(x) = k_2 * x, \text{ where } k_2 = (dTR/dx) \quad (3)$$

where

C = Total Cost, FC = Fixed Cost, VC = Variable Cost and TR = Total Revenue.

x = amount of units, tonnes, litres, etc., of a certain waste fraction

Setting TC = TR allows us to obtain the critical point for the quantity of waste required (in kg, tonnes, liters or other units) to fully justify, in purely economic terms, collection of the fraction in question. In terms of accounting practices in Sweden (Gerdin, 1995), the estimated costs are allocated in the following manner:

$$\text{TC/item} = [\text{estimated VC/calculated quantity of items}] + [\text{estimated FC/normal quantity of items}] \quad (4)$$

This estimation method is particularly useful when applied to companies that, for the most part, produce only one kind of product.

Average cost estimation method

Another approach, the *average cost estimation* method, can be used when considering a company producing one product only. It involves simply dividing the total cost for the period in question by the total production during that period, resulting in the cost per ton, or litre etc.

This study proposes that when applying the average cost estimation method, the cost of a given waste fraction is determined by multiplying expression (1) by the actual or budgeted average cost for the period in question.

Equivalent method of cost estimation

The third method to be considered in connection with the separation of waste fractions is the *equivalent method of cost estimation.* This method can be applied to companies producing a limited number of different products, all based on essentially the same raw material and involving similar manufacturing procedures. The calculation of the equivalent rate (ER) for a particular product during a given period is carried out in accordance with equation (5).

ER = (normal cost per unit for a given product) / (normal cost per unit for the product with the lowest cost per unit) (5)

Absorption costing method

The fourth method, the *absorption costing* method, involves a step-by-step analysis of the contribution of the separate costs to the final cost units, taking the following into account: the distribution of direct costs in the final cost units; the distribution of indirect (overhead) costs in the sub-organizations involved (such as departments); and the distribution of the costs of the sub-organizations involved in the final cost units. Estimates for a given product are made as shown in Table 2, where: DM is the direct material costs; MO is the material overhead costs; DL is the direct labour costs; PO is the production overhead costs; AO is the administrative overhead costs; SO is the sales overhead costs and S, G & A rate are the sales, general service and administrative expenses.

Table 2. Basic set-up for the absorption costing method.

DM	(Direct material costs)
+ MO	(MO = DM * absorbed indirect material costs rate)
+ DL	(Direct labour costs)
+ PO	(PO = DL * absorbed production overhead costs rate)
=	Production costs
+ AO + SO	(AO + SO = Production costs * S, G & A rate)
=	Total cost

Activity Based Costing method

The *Activity-Based Costing (ABC) method* is the fifth method to be reviewed. This method is based on the fact that if many of the costs arise from factors that are non-volume-based, the ABC method is clearly applicable. The aim is to trace costs to products or services instead of arbitrarily allocating them (Johnson & Kaplan, 1987). As costs are often linked to the number of transactions involved in the activity in question, ABC is also called *transaction-based costing*.

Although applying the allocation principles contained in expression (1) to the estimation methods described above redistributes the cost of regular products to waste, this does not necessarily result in an increase in the *total* cost volume for the company involved. Moreover it does not directly link the avoidance of waste with the incentive to reduce the total cost as specified in the consolidated profit and loss account used for business purposes. Weights can be applied, however, to adjust the costs connected with a particular type of waste to its environmental impact, based on scientific evidence and/or in terms of overall societal aims.

“Environmental shadow prices” should therefore be used in combination with the cost allocation principle in defining environmental standards.

Contribution margin analysis

Contribution margin analysis involves the assumption that, within certain limits, the fixed cost of a product is basically independent of the number of units manufactured or sold, and only the variable cost changes. The contribution margin of a product can be defined as the difference between the sales revenue and the variable cost of the product in question. The decision of whether to commercialise a given waste fraction can be facilitated by assessing the contribution margin connected with it, in the manner shown in Table 3.

Table 3. Scheme for estimation of the contribution margin, shown here for the fraction of waste sold.

	Income from sale of the fraction sold
-	Variable cost of the fraction sold
=	Contribution margin covering the fixed cost
-	Specific fixed cost of the fraction in question
=	Contribution margin after deduction of costs traceable to the fraction, also called “operating income”

If a positive value is obtained in the bottom line, this generally means that the waste fraction in question should be turned into a product and not simply be dumped or discarded.

Polluter-Pays Principle

A commonly suggested way to cope with the pollution aspect of the waste problem, is to apply the Polluter-Pays Principle (PPP); that is to let the polluter carry the costs of the pollution prevention and the control measures that he originates, the latter being measures decided by public authorities to ensure that the environment is in an acceptable state (OECD, 1992).

At the Rio de Janeiro top summit in 1992, The United Nations Conference on Environment and Development (UNCED), stated that: “Governments,… should apply the PPP whenever appropriate,… through setting waste management charges at rates that reflect the costs of providing the service and ensure that those who generate the wastes pay the full cost of disposal in an environmentally safe way;” (UNCED, 1992). This study proposes that, transferred to an internal business economic context, a first step to apply this principle, would be to allocate all the necessary costs incurred in making the production process environmentally friendly in a company - which are called the environmental adjustment costs - to the residual waste products involved. The PPP is applied according to the EUROPE model to construction waste from a site.

This study furthermore proposes that expression (1), when multiplied by the environmental adjustment costs that accrue, yields the costs connected with waste that are referable to a particular industrial activity with environmental repercussions, in order to induce corporate waste-reducing incentives that lead to cleaner production processes.

Construction waste management case study; Block Opus 1

Project description

The construction project consisted of three three-storied houses with two flats per storey, thus in total eighteen flats. Opus 1 was built by the construction company JM Bygg AB between August 2001 and September 2002. The total cost of production was approx. MEUR 3.50 excluding purchase of land but including MEUR 1.42 for materials and MEUR 0.33 for expenses including costs for garage and storehouse. At the time of writing, that is February 2003, EUR 1 equals approx. SEK 9.15 and USD 1.08.

Construction description

Each level in Opus 1 has 300 m^2 (30 m X 10 m) and the three-level houses give a total area of 2700 m^2. There are four garages of 128 m^2 each. The ceiling height is 3 m which gives a total construction volume of approx. 9600 m^3.

Waste handling system

The waste handling system of Opus 1 meant that the workers emptied the vats into containers that were placed in the yard. The transportation company Akka Frakt AB transported the wastes to the recovery yard of the waste management company SYSAV using containers at a total cost of about EUR 5,304 including rent for containers and fees for tipping. Fifteen percent of that cost consisted of miscellaneous items. SYSAV tipped at the waste reception plant Spillepeng or in Trelleborg for a total waste fee of EUR 5,879.

Waste statistics

The waste that occurred at Opus 1 was broken down into different fractions given in Table 4.

Table 4. Breakdown of main waste fractions from Opus 1.

Fraction	**Weight (tonnes)**	**Breakdown (%)**
Unpainted wood	2	1.9
Combustible materials	34	32.4
Scrap iron	7	6.7
Cast concrete	14	13.3
Pure gypsum	12	11.4
Waste to assortment and deposit	36	34.3
Total	**105**	**100.0**

The costs as well as weights for wastes from Opus 1 for different fractions with respect to construction sub-components are shown in Table 5.

Table 5. Combined breakdown of costs and weights on construction sub components for wastes at Opus 1.

Sub component	**Breakdown (%)**
Electrical sub-contractor	1
Heating and plumbing sub-contractor	1
Ventilation sub-contractor	1
Painting sub-contractor	1
Floor sub-contractor	1
Trabeation (gables including gypsum wallboard for facades)	5
Framework; cast concrete	20
Framework; reinforcement	5
Larch panel and minerit (Swedish) material	30
Mineral wool; wet materials and spillage	15
Gypsum wallboard inner walls	10
Miscellaneous	10
Total	**100**

The analysis of waste management models when applied to materials from the case study Block Opus 1

Cost benefit analysis

There are no estimations available of variable and fixed costs for Opus 1. Therefore, in this case, the method of *overhead rates based on normal capacity* that is based on the existence of figures for variable and fixed costs cannot be applied in a construction waste management perspective.

The *average cost estimation method* is useful since it is possible to look at for example gypsum wallboard inner walls. According to Table 5, gypsum wallboard inner walls account for 10% of the total cost for wastes. This means approx. 10% of EUR 5,879 for the SYSAV waste fees + 10% of (EUR 5,304 * 85% for the Akka transportation fee excluding 15% miscellaneous) = 10% * EUR 10,387 = EUR 1,039.

Using costs that are known as the distribution parameters is realistic and can be expected to provide representative figures due to a reasonable correlation between, for example, quantities and costs. This correlation is expressed in Table 5 as single digit values that show the combined proportion for costs as well as weights for construction sub-components for wastes at Opus 1. (See also “Waste statistics” above.) Using expression (1) adapted to the cost-related conditions of Opus 1 gives the proportionality factor [EUR 1,039 / (MEUR 3.50 + EUR 10,387)] = 0.03%

This gives the estimation of the cost referable to gypsum inner wallboard waste as follows: 0.03% * MEUR 3.50 = EUR 1,049 to be allocated to the fraction in question.

This gives a shadow price cost per tonne of the waste fraction of EUR 1,049 / 11.4 tonnes EUR 92 to be allocated to each tonne of the waste fraction (Table 4). This can be compared with an average cost per tonne for spillage of gypsum wallboard of approx. EUR 328 excluding the cost of labour (Stenis, 2002). This indicates that the use of the equality principle on the average cost estimation method in a construction waste perspective is a reasonable approach, giving reasonable costs per unit of waste to be allocated.

The *equivalent method of cost estimation* is useful when the industry studied is producing a limited number of different products. Furthermore, so-called equivalent rates are never used in connection with construction objects. Therefore, the equivalent method of cost estimation cannot be applied in a construction waste management perspective.

The *absorption costing method* is not used at all in construction industry to the same extent as in regular producing industry because there are no standardised special mark-ups that are used in construction industry for such items as production, materials, administration and sales. Every construction object has its own specially adapted estimation without standardised mark-ups since construction objects usually differ from other construction objects to a large extent. Therefore, it is not possible to apply the "pure" absorption costing method in a construction waste management perspective.

If the equality principle concept introduced considering the *ABC method* is applied to construction objects, the result will be just a total sum to split up to parts connected to certain waste fractions similar to the calculation for the average cost estimation method performed above. It would be rather meaningless to take a roundabout route using the ABC method to get this figure. Therefore, in practice the "pure" ABC method cannot be applied in a construction waste management perspective in terms of the scientific theory developed in this study.

Contribution margin analysis

In a construction object, there are no included single products produced that can be profitable and give a positive contribution margin in the traditional industrial way. Since the contribution margin analysis method is based on the existence of figures for variable and fixed costs and since such figures, as discussed earlier, are not available, it is not suitable for application in a construction waste management perspective.

Polluter-Pays Principle

Source separation of wastes can be said to be an activity that makes the production process in a construction company environmentally friendly. Therefore, this can be used as an example here. According to the site manager (Ilvemark, personal comm., 2003) the waste source separation at Opus 1 saved an additional 50% of the SYSAV tipping fee. This gives revenue of 50% * EUR 5,879 = EUR 2,939.

The investment cost can be said to consist of four additional containers instead of just one container that would have been enough to use if waste separation had not been applied at Opus 1. This gives an investment cost, for example the rent, of EUR 5,304 * 85% * 4/5 = EUR 3,607. This gives an environmental adjustment cost for making the production process environmentally friendly in the company of EUR 2,939 – EUR 3,607 = EUR 667.

According to the theory developed in this study, applied on the gypsum wallboard inner wall waste fraction as above, this environmental adjustment cost is multiplied by the proportionality factor calculated above giving a shadow price loss from the investment per tonne of waste as follows (see Table 4): (EUR 667 * 0.03% / 11.4 tonnes) = EUR 0.018 to be allocated to each tonne of the waste fraction. This can be compared with the example above giving a cost per tonne for spillage of gypsum wallboard of approx. EUR 328 excluding the cost of labour. This indicates that the use of the equality principle on the Polluter-Pays Principle in a construction waste perspective is a most reasonable approach giving most reasonable costs per unit of waste to be allocated.

Collocating analysis

As shown above, the possibilities for applying the equality principle introduced previously (Stenis, 2002) are best for the average cost estimation method and the Polluter-Pays Principle approach. In particular, the average cost estimation method gives reasonable results when tested on actual conditions, whereas the Polluter-Pays Principle application obviously requires substantial revenues and/or investment costs to produce costs that are worth allocating to the waste fractions in question. In other terms, application of the Polluter-Pays Principle in a construction waste perspective normally is expected to give financial corporate incentives that are too small to justify its use.

Environmental impact weights can be applied to construction waste to adjust the costs connected with a particular type of waste to its environmental impact as based on scientific evidence and/or as viewed in terms of overall societal aims. Therefore, the average cost estimation method should be the preferred alternative to allocate costs to wastes when fulfilling the ambition to apply the equality principle on construction waste management.

The prevailing paradigm for solid waste management has, in Sweden for example, shifted from “getting rid of the problem” during the 1950s and 1960s to the emphasis on treatment methods in order to reduce the waste amounts based on increased legislation during the 1970s and 1980s. This was followed by the ambition of recovering energy from waste and the implementation of the “waste management hierarchy”, (e.g. prevention of waste generation, recycling or reuse, incineration or biological treatment and landfilling) combined with a commercial approach to waste. During recent years, the authorities have to an increasing extent adopted taxation of waste depositing in order to minimise the landfilling in favour of incineration (Nilsson, 1997).

The next step, the author proposes, should be the equalisation of waste with regular products in financial terms – the equality principle. This is consistent with the prevailing sustainable development concept. The industrial production, including waste generation, the patterns of material and product flow and the related economics must be carefully analysed and an optimisation due to factors as resources, energy and capital must be carried out and the equality principle introduced.

Therefore, this study represents a change of waste management paradigms in that it claims to imply the ultimate financial consequences of, to a full extent, equalisation of (industrial) waste with regular products. This is a step beyond the producer responsibility concept. By the ultimate enhancement of the status of industrial waste in this study, finally industry has the tool necessary to make the sustainable development ideal come true *in practice*.

Discussion and conclusions

As regards the construction waste management applicability, as shown in the construction site case study Opus 1, a high potential exists for applying the equality principle to a construction waste management context. The findings from the Opus 1 case study point in the direction of a high degree of applicability in the real world due to the reasonable results that have been obtained. In particular this statement is most relevant for the average cost estimation method but also, to some extent, for the Polluter-Pays Principle application approach. A previous study by the author (Stenis, 2002) have shown that the equality principle is generally applicable to industrial waste management conditions and gives reasonable results when applied in the same "famous" real world.

In this presentation, only two – the average cost estimation method and the Polluter-Pays Principle application approach - out of a total of seven reviewed methods and principles are considered to be relevant to be applied in a construction waste management context. The reason for this is that only these two methods give reasonable results, as regards the shadow price cost to be allocated to each tonne of the gypsum wallboard waste fraction studied here, when tested on actual conditions. This implies that it is most important to carefully scrutinize different methods with regard to their possibilities to be applied in a given context, such as construction waste management.

This study presents a principle for estimation of waste-related industrial company shadow price costs and revenues, which constitutes the basis for estimation of the "full" company cost and estimation of the "true" company business financial result in a waste management context. This has an impact on the related consolidated profit and loss account, budgets and forecasts etc., due to the general application of the equality principle introduced as a basis for items such as future novel construction-waste-related official recommendations and demands and voluntary environmental agreements. This is, in fact, an unavoidable consequence of the steadily increasing demand from society for construction companies to act in accordance with the principle of sustainable development.

The efforts in this area represent a shift in waste management paradigms. This shift is consistent with the concept of sustainable development.

The outcome and benefits from the present study are summarized here.

1. Elaboration of a principle for estimation of construction waste-related company costs and revenues.
2. Implication of construction industry cost-saving incentives.
3. Reduction of waste at the source, leading to less waste produced.
4. Extended environmental good will from adequate waste management.
5. Enhanced status of construction waste due to a new way of regarding such waste as being equivalent to regular products in financial terms.
6. Proposal for a shift of waste management paradigms.

Acknowledgements

The author would like to thank Professor William Hogland, Department of Technology, University of Kalmar (Sweden), Professor Lennart Mathiasson, Department of Analytical Chemistry, Lund Institute of Technology, Lund University and Professor Kerstin Barup, Head of the Department of Construction and Architecture, Lund Institute of Technology, Lund University (Sweden) for their constructive comments on this work. The author is also grateful to the University of Kalmar, the Kalmar Research and Development Foundation – Graninge Foundation [*Kalmar kommuns forsknings- och utvecklingsstiftelse – Graningestiftelsen*], the Knowledge Foundation [*KK-stiftelsen*], The Swedish Association of Graduate Engineers [*Sveriges Civilingenjörsförbund (CF)*], The ÅF Group [*AB Ångpanneföreningen (ÅF)*], The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning [*Forskningsrådet för miljö, areella näringar och samhällsbyggande (FORMAS)*] and The Development Fund of the Swedish Construction Industry [*Svenska Byggbranschens Utvecklingsfond (SBUF)*] for financial support.

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