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Industrial Management Models with Emphasis on Construction Waste

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Industrial Management Models with Emphasis on Construction Waste

Doctoral thesis

Jan Stenis

Abstract

Increased attention is nowadays devoted to waste management. The objective of this work is to analyse how commonly known business economic models and methods, as well as the Polluter-Pays Principle, can be applied to waste management in general and to waste fractionation in particular, so as to facilitate environmental optimisation of industrial and construction waste fractionation. In discussing the functionality of the modified models arrived at, systems theory is applied in order to get a scientifically adequate picture of the societal context of the models.

A further objective is to investigate certain aspects of construction waste management economic model theory through case studies. Thereby, the applicability of modified versions of the above mentioned business economic models applied in construction waste management is tested. Generally, the work is performed in order to provide flexible management instruments adapted to changing demands.

The economic model methods are studied and modified from a waste management point of view. In this context, the "equality principle" introduced earlier (Stenis, 2002), interpreted as equality between (industrial) waste and normal products in business economic terms, is applied. "The model for Efficient Use of Resources for Optimal Production Economy (EUROPE)", is introduced for assigning industrial costs and revenues to waste by the employment of so-called shadow prices. The modified, mainly cost assessment oriented, methods are evaluated from a business economics perspective in relation to waste management.

The effort in this work represents a shift of views within the field of waste management. This shift is consistent with the concept of sustainable development. Also, the present study represents general environmental and financial advantages for society at large.

It is concluded that the findings point at the partly fruitful possibility to modify commonly used cost benefit estimation methods and contribution margin analysis including the Polluter-Pays Principle (PPP) in a practical industrial and, to a certain extent, a practical construction waste management context by the use of the equality principle. Therefore, it can be said that construction waste management can be carried out by using certain (modified) economic models.

Summarised, the major findings of the work are as follows:

1) Presentation of an alternative way of looking at industrial waste in a business context;
2) Introduction of the EUROPE model for assigning costs to industrial waste to be used in conjunction with the introduced equality principle to provide long term recommendations regarding waste involving the use of "environmental shadow prices";
3) Presentation of how the Polluter-Pays Principle can be incorporated into the financial accounts of a manufacturing company by the employment of the equality principle in conjunction with the introduced concept of the "environmental adjustment cost";
4) Proposal for a shift of views within the field of waste management.

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Summarised, the recommendations for the future in this work are as follows:

1) As regards *general industrial conditions*, commonly used cost benefit methods, the contribution margin method and the Polluter-Pays Principle approach are suggested to be applied in a modified way through the use of the EUROPE model, the basis being the equality principle introduced.
2) As regards *construction management conditions*, the average cost estimation method is suggested to be applied in a modified way through the use of the EUROPE model, the basis being the equality principle introduced.

Keywords: Economic models, integrated industrial waste management, construction waste, cost benefit analysis, contribution margin analysis, Polluter-Pays Principle, sustainable development.

Abstract (in Swedish)

Avfallshantering ägnas nuförtiden ett ökande intresse. Detta verk syftar till att analysera hur vanligt förekommande företagsekonomiska modeller och metoder liksom principen om att förorenaren betalar (The "Polluter-Pays Principle" (PPP)), generellt kan appliceras på management av avfallshantering och specifikt på segregering av olika avfallsfraktioner i syfte att medge miljömässig optimering av fraktionering av enkannerligen industriellt avfall och byggavfall. Vid diskussionen kring funktionaliteten hos de modifierade modeller som erhålls, tillämpas ett systemsynsätt i syfte att erhålla en vetenskapligt adekvat uppfattning om den samhälleliga kontexten kring modellerna ifråga.

Ett ytterligare syfte är att undersöka beskaffenheten av vissa aspekter av hantering av byggavfall med hjälp av fallstudier som genomförts. Därigenom testas tillämpbarheten i ett byggavfallsperspektiv av modifierade versioner av ovan nämnda företagsekonomiska modeller. Allmänt sett är arbetet utfört i syfte att tillhandahålla flexibla instrument för management av industriellt avfall och byggavfall med hänsyn taget till föränderliga krav.

De ekonomiska modellerna studeras och modifieras ur ett avfallshanteringsperspektiv. I detta sammanhang tillämpas den tidigare lanserade "jämställighetsprincipen" (eng. "the equality principle") (Stenis, 2002) som ska förstås som likvärdighet mellan (industriellt) avfall och reguljära produkter i företagsekonomiska termer. Europamodellen (eng.: "the model for Efficient Use of Resources for Optimal Production Economy (EUROPE)") lanseras i syfte att allokera industriella kostnader och intäkter till avfall med användande av så kallade skuggpriser. De modifierade, huvudsakligen kostnadsberäkningsinriktade, metoderna utvärderas sedan ur ett ekonomiskt lämplighetsperspektiv relaterat till avfallshantering.

Ambitionen i detta verk representerar ett förändrat synsätt inom kunskapsområdet avfallshantering. Denna förändring är i enlighet med konceptet för ett uthålligt samhälle. Föreliggande studie representerar även allmänna miljömässiga och ekonomiska fördelar för samhället i sin helhet.

Slutsatsen dras att rönen pekar på en delvis fruktbar möjlighet att de facto kunna modifiera vanligen använda metoder för kostnadsintäktsanalys och täckningsbidragsanalys, inklusive applicering av PPP, på industriellt avfall och, i viss utsträckning, på byggavfall i ett praktiskt sammanhang genom tillämpning av jämställighetsprincipen. Hantering av industriellt avfall såväl som byggavfall kan därför sägas vara möjligt att bedriva baserat på användning av vissa (modifierade) ekonomiska modeller.

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Sammanfattat är de huvudsakliga resultaten av föreliggande arbete som följer:

1) Lanserande av ett alternativt sätt att se på industriellt avfall i ett företagsekonomiskt sammanhang;
2) Introduktion av EUROPA-modellen för allokering av kostnader till industriellt avfall för användning tillsammans med den lanserade jämställighetsprincipen i syfte att tillhandahålla långsiktiga rekommendationer rörande avfall innefattande användning av "miljömässiga skuggpriser";
3) Presentation av hur principen om att förorenaren betalar kan "byggas in" i ett tillverkande företags räkenskaper genom användande av jämställighetsprincipen tillsammans med det lanserade konceptet för "miljömässig anpassningskostnad";
4) Presentation av förslag på ett förändrat synsätt inom avfallshanteringsområdet.

Sammanfattat är rekommendationerna för framtiden i föreliggande arbete som följer:

1) Beträffande *allmänna industriella förhållanden* så föreslås vanligen använda metoder för kostnads-intäktsanalys, täckningsbidragsmetoden och principen om att förorenaren betalar, användas i ett modifierat utförande genom tillämpning av EUROPA-modellen som baserar sig på den introducerade jämställighetsprincipen.
2) Beträffande *förhållanden för byggledning* så föreslås genomsnittskalkyl användas i ett modifierat utförande genom tillämpning av EUROPA-modellen som baserar sig på den introducerade jämställighetsprincipen.

Nyckelord: Ekonomiska modeller, integrerad industriell avfallshantering, byggavfall, kostnads-intäktsanalys, täckningsbidragsanalys, principen om att förorenaren betalar, uthållig utveckling.

Preface

In the *Report of the United Nations Conference on Environment and Development* (UNCED, 1992), and also in Agenda 21 of the United Nations, it is stated, "…the (General) Assembly affirmed that environmentally sound management of wastes was among the environmental issues of major concern in maintaining the quality of the Earth's environment and especially in achieving environmentally sound and sustainable development in all countries."

One of the biggest problems in the European Union environmental policy is the ever more growing waste mountain. The Sixth European Community Environment Action Programme *Environment 2010: Our Future, Our Choice* (The European Commission, 2002) emphasises the need for breaking the relationship between economic growth and production of waste. In particular, measures will be taken to increase recycling and attempts will be made to reach the preventive waste production targets through application of an integrated product policy.

With regard to construction waste management in particular, the situation is generally equally alarming. In Stockholm, the capital of Sweden, for instance, the construction waste management situation has recently started to get out of control. This is the view of companies in the construction industry who report that the severe problems may lead to the occurrence of illegal dumpings due to, for example, excessive taxation of (construction) waste (Appelgren, 2001). Generally, most manufacturing plants need detailed analysis of their waste management at all stages of the system. Those who have already studied waste streams within the company and who have identified opportunities for recovery and resource saving, usually find, however, that there are large economic as well as environmental benefits to be gained when appropriate waste management is implemented (Paper IV).

However, the literature study performed showed that business economic theory aspects in the waste management field being rare. This was supported by the outcome of the survey conducted by the author in 2002, the result being that the turnover top ten Swedish industrial companies do not use advanced business economic models at all when calculating on their waste management (Paper II). A previous survey performed in 2000 by the author showed that business economic models are virtually not at all used as a basis for waste management decision-making within major Swedish industry (Paper II).

Furthermore, according to the United Nations Economic and Social Council, Commission on Sustainable Development, waste production rates in both developed and developing countries are increasing at unprecedented rates. Many cities are currently close to a crisis situation with regard to the environmental and health costs related to solid waste management. In fact, some cities have already experienced epidemics that have resulted in significant economic losses from reduced tourism and export potential, not only attributed to bad waste management, but to other sanitation issues, such as waste water collection and treatment. The urban poor are the hardest hit in relation to their direct living environment. With the increasing trend towards privatization of services and the drive for increased efficiency, there is an increasing need for legislative frameworks which enable satisfactory regulation of solid waste collection and disposal (UN, 2001).

During the past decade, the amount of waste generated in Europe has grown by approx. 10% per year. It is clear that this trend must be stopped and reversed if the Europeans want to avoid being submerged by rubbish (European Commission, Environment DG, 2000). Total

waste generation increased by about 15% in Europe between 1995 and 1998, while the gross domestic product (GDP) in the same period grew by about 10% (Wallström, 2001). Despite the fact that extensive waste recycling is employed, waste generation in Europe is still increasing steadily. (European Environment Agency, 2003, pp. 154-157). In the U.S.A., more people are recycling than ever before, but the recycling rate of 28% is hardly keeping up with the rate of waste generation (Skinner, 2003).

Approx. 740 million tonnes of waste are generated by the manufacturing industry in Europe every year. This corresponds to roughly one tonne of manufacturing waste per person per year. In Western Europe (i.e. The European Union, Iceland, Liechtenstein, Norway, Switzerland (EFTA) and the small states, Andorra, Monaco and San Marino), industrial waste accounts for about 15% of the total waste generated. For comparison, municipal waste accounts for about 14% of the total waste generated in Western Europe. Levels of manufacturing waste have increased since the mid-1990s in most European countries for which data are available (European Environment Agency, 2003, pp. 154-157). This is not compatible with the concept of sustainable development; sustainability generally being defined as capable of being maintained at a steady level. In terms of natural resources, sustainability implies balance in their use and replenishment (Reijnders, 2000, p. 122. Paper II).

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 has generally increased during the 1990s (European Environment Agency, 2003, p 159).

In line with the attention devoted to the issue of waste management by such organisations as the United Nations and the European Union, and considering the statistics as presented above, to conduct studies of industrial and construction waste management can be considered a relevant contribution to the societal sustainability. The present study is hoped to contribute to planning and decisions concerning industrial and construction waste management and the policy to be adopted to best further an environmentally friendly and economically profitable approach to industrial and construction waste management. The work is regarded as filling a "research gap", literature on the economic management of waste being sparse (Pearce and Brisson, 1995). It is hoped that the study will be useful inter alia as an overview of certain economically related industrial and construction waste management models and their possibilities to be developed in order to achieve an improved environment by the use of alternatives to taxes and fees as the main regulatory instruments.

In order to achieve a clean enough environment, industrial waste must namely as far as possible be eliminated. This requires a direct linking between the very existence of waste and company profits. This implies a new way of looking at industrial and construction waste where the central paradigm is that the waste is given the same status as regular products from a business economic point of view. This has consequences for inter alia the principles for the allocation of costs to the waste, which, if applied, gives the industry very strong incentives to reduce, or rather eliminate, the waste by implementation of new waste management models. If not so, the realization of the clean enough industry and construction industry will take place only slowly, this being the main reason why, to a certain extent, a shift of paradigm is needed. In doing this, a more sustainable society can be achieved. It can encompass a larger quantity of high-quality products produced per unit of time at a lower cost than today.

Reading instructions

Relation to earlier work

The present work is the continuation of the work presented in the author's licentiate dissertation (Stenis, 2002). The earlier work describes an attempt to investigate whether well-known economic models and methods can be applied to the context of industrial waste management in order to improve the environment as well as corporate profits. As the next step in the development of the concept introduced in the licentiate dissertation, the present work also attempts to cover construction waste in the research area of residual products. This is regarded as being highly motivated since, as mentioned in the preface, "Waste generated from construction and demolition activities, including the renovation of old buildings, accounts for about 32% of all waste generated in Western Europe." (European Environment Agency, 2003).

In doing so, the present work investigates whether use of the equality principle, first introduced in the licentiate dissertation, and now backed up in this work by, for example, three new articles regarding industrial waste in connection with cost benefit analysis, contribution margin analysis and the Polluter-Pays Principle, is a fruitful path to follow in order to illustrate strong financial incentives for construction companies to drastically reduce their generation of construction waste at the source. Therefore, the present work should be interpreted as an extension of the licentiate study into another significant area of waste management except from being a general presentation of how to apply business economic theory concepts to industrial waste management in a new way that gives financial incentives for the reduction of residual products production. It should thus be borne in mind that many sub-sections of waste (and energy) management remain to be explored with respect to the possible application of the equality principle.

A three-fold comparison is made in this thesis regarding the possibilities to apply the developed theory concerning the following phenomena to compare:

1) Mechanical industry versus bulk product industry. (This is most relevant for the work performed presented in the licentiate dissertation which, however, is incorporated in the present work);
2) Mechanical industry and bulk product industry versus construction industry. (This is most relevant for the further development of the research presented in the licentiate dissertation into the present doctoral research. In particular, applications *in practice* of cost-benefit analysis, contribution margin analysis and the Polluter-Pays Principle (PPP), are not presented in the licentiate dissertation, but are analysed thoroughly in the present work);
3) Various economic models which are used and modified in a suitable way in the current development of the theory build-up are compared aiming at improving the environment and economy in general.

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The structure of the work

This work is divided into eight major parts. The first one is the main report. The other seven parts are the six different papers followed by calculations in Appendix 7 (see Fig. 1).

In this work, a broad investigation of management options constitutes the basis for inter alia an attempt to obtain management tools to solve daily waste management problems in industry and in construction industry as well. Therefore, after the introduction and methodology description in *chapter 1* and *chapter 2*, in *chapter 3* a comprehensive review is presented of the results that are obtained. The economic models that are studied are reviewed with regard to the possibilities of modifying them according to a waste management perspective based on the findings in the appended papers. Also, the results from the construction site case study that is performed are presented. In *chapter 4*, the nature of this chapter of analysis is presented and amplified with a discussion about the applicability of the theory to industrial waste and construction waste management conditions. The model modification effort is evaluated from a construction waste related economics perspective, the general objective of the work being to make a comparison between industry and construction industry with respect to the applicability of *the equality principle* introduced earlier (Stenis, 2002) to construction waste management. The chapter ends with a summarising statement of the view presented in this work as regards ways of how to making construction waste management systems more efficient. This is followed by a summary in *chapter 5* of the conclusions reached at. The work is ended by *chapter 6* as an outline of possible avenues for further research based on the current findings.

The main report
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Chapter 1. Introduction
Chapter 2. Methodology
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Chapter 4. SHOULD BE-mode
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Chapter 6. Further research
Reference list

Appendix 1. Paper I

Appendix 2. Paper II

Appendix 3. Paper III

Appendix 4. Paper IV

Appendix 5. Paper V

Appendix 6. Paper VI

Appendix 7.

Figure 1. The structure of the work.

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The papers in the thesis

The findings in the main report are supported by the six appended papers. These papers will be referred to in the text by their Roman numerals as follows:

I.   Stenis J. **Environmental Optimisation in Fractionating Industrial Wastes Using Cost-Benefit Analysis**. *Resources, Conservation and Recycling* 2004;41(2):147-164.

         This paper examines the possibilities of using cost-benefit analysis methods in the industrial waste fraction environmentally friendly management context and explains the theory of the methods.

         <u>Major results of Paper I</u>

       1.   Presentation of the equality principle involving the use of "environmental shadow prices".
       2.   Application of the equality principle to the following major cost-benefit analysis methods:

            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
            6.   Remainder method

       3.   Presentation of a new way of regarding waste in a business context.
       4.   Bringing about a change in the perceived status of industrial waste by emphasising the financial impact of the costs and revenues involved in the use of shadow prices.

II.   Stenis J. **Environmental Optimisation in Fractionating Industrial Wastes Using Contribution Margin Analysis as a Sustainable Development Tool**. *Environment, Development and Sustainability* 2005. In press.

         This paper examines the possibilities of using the contribution margin analysis method in the industrial waste fraction environmentally friendly management context and explains the theory of the method.

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Major results of Paper II

1. Introduction of the model for Efficient Use of Resources for Optimal Production Economy (EUROPE) in assigning costs to industrial waste, for use in conjunction with the equality principle presented here in order to provide long-term recommendations regarding waste involving the use of "environmental shadow prices".
2. Presentation of the way in which the contribution margin analysis method can be modified in accordance with the equality principle, so as to provide environmental management guidelines for short-term product cost and investment assessment applicable, in particular to consolidated profit and loss accounts, budgets and forecasts for external use.

III. Stenis J, Hogland W. **The Polluter-Pays Principle and its Environmental Consequences for Industrial Waste Management**. *Environment, Development and Sustainability* 2002;4(4):361-369.

This paper discusses the environmental consequences as a result of the use of the Polluter-Pays Principle (PPP) and gives suggestions of principles for how the producing industry can internalise waste related environmental costs in compliance with the PPP.

Major results of Paper III

1. Introduction of the concept of the "environmental adjustment cost" to assign all costs connected with making the production process of a company environmentally friendly to the residual waste products involved, for use in conjunction with the equality principle, in order to provide the company with a financial incentive for reducing waste.
2. Presentation of how the Polluter Pays-Principle can be incorporated into the financial accounts of a manufacturing company by the employment of the equality principle, in conjunction with the introduced concept of the "environmental adjustment cost".

IV. Hogland W, Stenis J. **Assessment and System Analysis of Industrial Waste Management**. *Waste Management* 2000;20(7):537-543.

This paper introduces the concept of integrated industrial waste management.

Major results of Paper IV

1. Identification of the most advantageous system for future waste handling at the company Stora, regarding environmental impact, energy balance and economy.
2. Provision of a step-by-step method of obtaining the optimal organisation of an industrial waste management system with respect to energy, economy and environmental impact.

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V.   Stenis J. **Industrial Solid Waste Management and Joint Production**. *Journal of Solid Waste Technology and Management* 2002;28(1):16-20.

This paper examines the possibilities to use the joint production theory for industrial waste management profitability estimation.

Major results of Paper V

1. Illustration of how joint production theory can be applied in estimating the profitability of fractionating industrial solid waste, a given product and the wastes produced in connection with its manufacture being regarded as a production-planning unit.
2. Presentation of a new approach for calculating the profit of different kinds of wastes that are produced jointly.

VI.   Stenis J. **Construction Waste Management Based on Industrial Management Models: a Swedish Case Study**. *Waste Management & Research* 2005;23(1). In press.

This paper describes a method of 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 model - the model for Efficient Use of Resources for Optimal Production Economy (EUROPE) - 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.

Major results of Paper VI

1. Creation of incentives for environmental improvement and profitability improvement in construction companies and other kinds of industry sectors as well.
2. Elaboration of a principle for estimation of construction waste related company costs and revenues.
3. Implication of construction industry cost saving incentives.
4. Reduction of wastes at the source, leading to less waste produced.
5. Extended environmental good will from adequate waste management.
6. Enhanced status of construction waste due to a new way of looking at such waste as equalized with regular products in financial terms.
7. Proposal for a shift of waste management paradigms.
8. General environmental and financial advantages for society at large.

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Other papers

VII.   Thörneby L, Hogland W, Stenis J, Mathiasson L and Somogyi P. **Design of a reverse osmosis plant for leachate treatment aiming for safe disposal**. *Waste Management & Research* 2003;21(5):424-435.

This paper, not included in the thesis, was produced during the doctoral programme and is related to the subject of the thesis. The paper describes reverse osmosis (RO) as one promising method for reduction of pollutant discharge. RO technology was tested at a pilot plant at Hedeskoga Landfill in southern Sweden.

Major results of Paper VII

1. The environmental management programme at Hedeskoga has confirmed that risk occurs of emission to nearby settlements caused by recirculation of RO retentate. However, because of its high nitrogen content, the permeate should not be discharged into a receiving water without treatment. Adding a nitrification step before the RO treatment could easily solve this problem.

Acknowledgements

Lund in October 2004

Jan Stenis

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1 Introduction

This chapter presents an introduction to the work. After a general waste management background, the general problem as well as the scientific problem is presented followed by an outline of the main objectives and delimitations of the work. A nomenclature is followed, finally, by presentation of the disposition of the work. The introduction in Chapter 1 in Stenis (2002) has been found to be useful and is thus also used here to a certain extent.

1.1 Historical perspective and the scientific context of this research

The ancient Greeks and Romans were known for their advanced sanitation. It is believed that the inhabitants of Knossos composted their organic waste, while the Romans had a well-organised culture including sanitation and public baths (Hogland (Ed.), 1996b). However, the decline of these cultures was followed by a general decline in public sanitation and hygiene (Berg, 1993). In mediaeval times, for example, people simply threw their rubbish into streets, where it rotted or was eaten by rats, pigs and dogs (Hogland (Ed.), 1996b).

The plagues that swept over Europe, decimating the population, made people aware of the importance of hygiene and sanitation. As urbanisation increased, it was no longer possible to employ the natural recycling possible in an agricultural community. As cities grew, the problem of waste grew with them (Berg, 1993). With the advent of the steam engine, and the industrial revolution, society had at its disposal a new source of energy, which led to greater production, higher consumption and more waste. The industrialised countries were now faced with the problem of waste management (Tiberg, 1995).

The concept of municipal waste collection was introduced into Sweden at the end of the 19th century, and a sorting plant was established in Stockholm at about the same time. During the 1950s and 60s people sorted milk bottle tops and newspapers, which were collected by recycling companies. However, refuse dumps and landfills rapidly grew out of all proportion, and it was realised that waste was in fact a resource and could be used for the recovery of material and energy (Hogland (Ed.), 1996b).

Attention also turned to the effects of pollution and waste on the global environment. Carson (1963) raised the alarm in her book *Silent Spring*, and following this people became increasingly aware of the environmental drawbacks of modern society. As a result of this, the United Nations launched a series of international environmental conferences. In 1972 *the United Nations Conference on the Human Environment* took place in Stockholm, Sweden (United Nations, 2003a). This was followed by *the United Nations Conference on Environment and Development* at Rio de Janeiro, Brazil, in 1992 (United Nations, 2003b). The latest international United Nations conference on this theme, *the World Summit on Sustainable Development* took place in Johannesburg, South Africa in 2002 (United Nations, 2003c). These conferences, together with the resulting, extensive, ongoing environmental debate, have put the environment on the global agenda as a major issue for the future.

On a more practical level, in large-scale industries, the conversion of waste into a product that resembles fuel for machinery is regarded as a task for machines. In small-scale industries, where modern technology is usually less prevalent, a common tendency is to process waste through source separation (Berg, 1993). As a result of the increased implementation of

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separation at source and lean waste technology, responsibility for waste is gradually being transferred to consumers and producers (Tiberg, 1995).

The amount of waste produced by building and demolition varies, depending on the level of activity in the building sector. It has also been found that building, and hence waste production, is strongly dependent on the state of the economy (Hogland (Ed.), 1996b).

Continuously emerging new directives regarding the "ecocycling society" or the "recycling society" place increased responsibility on the producer and dictate that landfilling be used only when material and energy recovery are not possible. The aim is to achieve long-term, sustainable development, based on the more efficient use of materials through a transition to cyclic material management. Generally, in a more and more closed-cycle-oriented society, it is a question of building up closed cycles, as illustrated in the simplified scheme in Fig. 1.1 (adapted from Hogland (Ed.), 1996b).
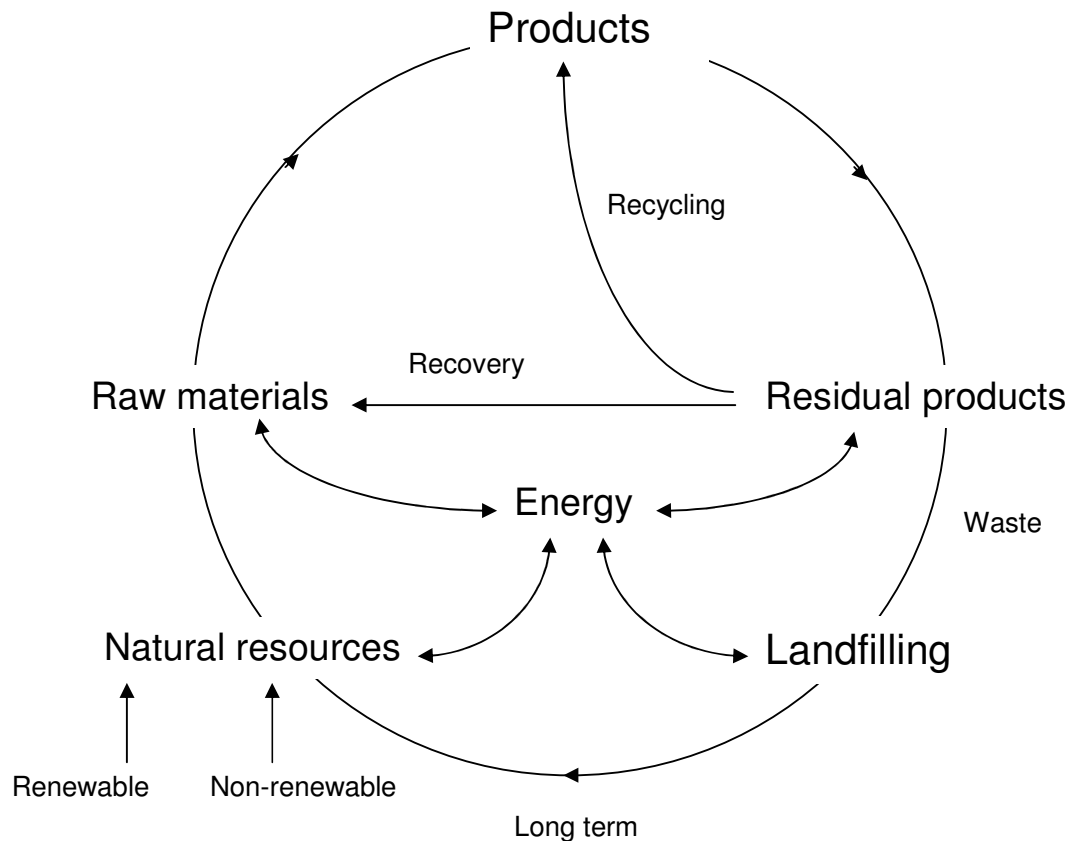
Figure 1.1 Fundamental closed cycles for products (after Hogland (Ed.), 1996b).

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As for other societal problems, the problem of waste is treated sector by sector. Solid waste, which is most visible and substantial, is treated as a problem by itself. Sewage is dealt with by another authority and chimney gas emissions by yet another. Solid waste is in turn divided into different kinds of waste such as municipal waste, industrial waste, hazardous waste, and so on. There is thus a considerable risk for sub-optimising solutions without an all-embracing perspective covering all kinds of waste (Tiberg, 1995).

In this context, the approach introduced in this work represents an effort to provide industry with an "umbrella solution" that is applicable to industrial waste generally. This approach provides a contribution to the fulfilment of the global ambition to control the growth of waste mountains. It is clear that this trend must be stopped and reversed if, for example Europeans want to avoid being drowned in rubbish (European Commission, Environment DG, 2000). The equality principle introduced in this thesis can be classified a novel concept (Paper I, II, III, V and VI), in particular since the work is regarded as filling a "research gap"; literature on the economic management of waste being sparse (Pearce and Brisson, 1995). Therefore, the approach presented here may well represent a useful way of coping with the global waste management problem, primarily in an industrial context, with good prospects for the future due to its high novelty value.

1.2 The need for waste management

The annual production of waste in e.g. Sweden in 1998 was about 94 million tonnes, of which 83 million tonnes comes from industry. Of this, approx. 14 million tonnes are recycled within the industry, including energy recovery, while 2 million tonnes are deposited on industrial tips. The equivalent of 550 kg per person per year, or 4.9 million tonnes, is non-branch-specific waste (including construction and demolition waste) that is also taken to tips (Statistics Sweden, 2002 and Swedish EPA, 2002).

However, interest in industrial waste as an important source of energy use and material recovery has increased considerably in recent years. Today, most factories are in need of a detailed analysis of their waste management at all stages of production. Factory owners who have already studied waste streams within the company and the possibilities of recovery and resource saving usually find that there are large economic as well as environmental benefits if adequate waste management is implemented (IEA Bioenergy, 1996).

The benefits of successful industrial waste management programmes aiming at minimisation of wastes are often manifested in significant reductions in manufacturing and production costs, more efficient use of valuable resources, improvements in process and product quality and reductions in waste generation, treatment and disposal costs. The additional benefits of industrial waste minimisation programmes may include a reduction in a generator's long-term liability for any hazardous wastes produced and the potential for positive publicity for being proactive and "doing the right thing" (Childers, 1998).

An equally substantial problem is also found within the construction industry. This can be exemplified by a practical example. Only about two thirds of gypsum wallboards in buildings are used since the spillage is approx. 33%. In Sweden today (2003), the cost of depositing the unsorted construction waste fraction is approx. SEK 1000 per tonne. This is equivalent to a depositing fee of approx. SEK 3 per m^2 of gypsum wallboard. Furthermore, the purchase price of gypsum wallboard is approx. SEK 25 per m^2. This is equivalent to a total of approx.

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33% * (SEK 3 + SEK 25) = approx. SEK 9 per m^2 for spillage excluding the cost of labour for handling the waste. This is equivalent to approx. SEK 30 for spillage per gypsum wallboard excluding the cost of labour. This example from the construction business also highlights the great need of waste management within construction industry as well as within industry (Stenis, 2002).

1.3 Societal waste management models

Society has certain environmental ambitions and targets. A common overall goal is to achieve sustainability as expressed e.g. by Agenda 21 (UNCED, 1992). In e.g. Sweden, the government has stated that the work to reach the environmental quality objectives is based on five fundamental principles: promoting human health, safeguarding biological diversity, protecting cultural heritage, preserving the long term production capacity of the ecosystem and ensuring that natural resources are properly managed. This is what is meant by ecologically sustainable development (Swedish Government Official Report (SOU) 2000:52).

The cost of environmental degradation in Sweden today is estimated at well over SEK 20 billion annually. This cost is made up, inter alia, of production losses, destruction of materials, impaired health, the loss of both cultural heritage and biological diversity (Swedish Governmental Official Report 2000:52). The cost can be compared to the Swedish national annual budget of about SEK 2200 billion (2003). The management of residual products is to a large extent a natural key factor in trying to achieve sustainable development. As mentioned in the preface, the UN, the EU and others pay great attention to the waste management problem in the context of reaching "environmentally sound and sustainable development in all countries" (UNCED, 1992). Therefore, society has a clear motive to engage in the process of developing new and useful waste management models.

The present work deals with industrial and construction residual products from an environmental and economic point of view. In this context, the most common public means of control is tax on residual products, e.g. waste tax. Today, there is an ongoing discussion about what waste management instrument models to use and particularly the suitability of waste taxes and fees. Taxes, as well as fees, levied on residual products have considerable drawbacks. Not unusually, taxes give rise to rigid systems and unexpected side effects since politicians do not always fully understand the consequences of their legislative efforts. This points in the direction of that there is a substantial need for a more efficient approach from society, partly based on the development of waste management models.

1.4 Corporate waste management models

Generally, the environmental costs of economic activity are not encountered until the assimilative capacity of the environment has been exceeded. Beyond that point, they cannot be avoided but will be paid by someone. The costs can be externalised - that is, transferred to various segments of the community in the form of the costs of damage to human health, property and ecosystems. Or they can be internalised - paid by the enterprise (WCED, 1987). Examples of the common approaches adopted for limiting such external effects are emission charges, emission standards, marketable permits and pollution taxes including destruction costs.

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Even though these approaches are proved to reduce the amount of pollution from industries, there is still a problem if, for instance, the prevailing pollution level is still so high that it is beyond the carrying capacity of the ecosystem in question. This affects the biodiversity in a negative way which is not in line with the concept of sustainable development (OECD, 1992). There may therefore be a need for stronger instrument development approaches, expressed in terms of e.g. new official recommendations and requirements for industrial waste management estimation that affects, for example, the consolidated profit and loss accounts for external use. Such a development may be a prerequisite as a step among others to make the industry act truly in accordance with e.g. the concept of sustainable development, maximum profit not being the one and only corporate motive anymore, even though it is so traditionally when making business economic estimates (Johansson, 1961).

In this context, it is important to look at the whole picture in order to make companies adapt to the environmental demands of society *in advance*, before the requirements are imposed. Designing means of control that take account of official requirements for accounting and restrictions can do this. In other terms, the need for adaptation to changed circumstances by maintaining a necessary preparedness for flexibility is a necessity for (producing) companies that want to stay in business. This need must thus be mirrored in the process of designing and applying new waste management model based instruments. In such a way, negative impacts related to waste can possibly be avoided.

One way to give a contribution to support the development of this process is to provide relevant education for managers in order to increase productivity. Maybe also a shift of generations is a prerequisite to adapt the prevailing mentality among management to current needs within industry.

1.5 Problem statement

Producing companies now and then behave in a way that damages nature. This jeopardises sustainability and causes negative reactions from the surrounding society. From a corporate management point of view, the problem therefore is how to achieve good enough production process control from an environmental point of view. Therefore, a corporate key management question is: "What means of environmental control for production process waste management should we have and apply?"

Companies depend on public environmental policy. Therefore, the control devices designed and applied must in a flexible way be able to meet the changing and ever more tightened environmental demands of society. Also, public opinion forces corporate management to take actions in advance to meet legislators' upcoming demands and thus increase their companies' chances of survival in the ever more fierce competition. It is of paramount importance in this respect to adapt to the public opinion and to make sure that the waste related activities of the company in question will be met by the public's acceptance and will be in accordance with international directives and agreements. A problem is to reach a comprehension as regards how important to companies this is and what they are doing about it concretely. Also ethical considerations are of importance in this context in a similar way.

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A common general problem for the manager is his lack of adequate environmental control instruments that match the changing demands of society. Usually, it is only profitability that is of importance when decisions are taken. Therefore, it is not certain whether the use of traditional control instrument models can cope with the upcoming, new demands of society.

In other terms, the manager needs a new "steering wheel" to cling to when navigating through the archipelago of increasing legislative waste management demands. Therefore, a task to fulfil, and a general problem to solve, at least partly, is to provide this flexibility promoting "steering wheel".

To conclude, a crucial problem in this context is how to make the managers' instruments match the societal demands in a way consistent with e.g. the Polluters-Pays Principle. Therefore, the paramount problem is how to scientifically meet the needs of the managers and give them new and flexible models as a basis for their management in the unique waste management surroundings.

Therefore, one general problem is how to fill this waste management research gap. A natural way to do this is to base the work on certain existing, commonly known management economic methods that must be reviewed in a representative and logical way and must be shown how they can be adapted in an adequate way.

1.6 Scientific problem

The problems of environmental, health and cost impacts justify a strong focus on the economics of waste management. Oddly enough, despite the importance of these issues, literature on the economic management of waste is only sparse (Pearce and Brisson, 1995). There are nevertheless numerous indications in the literature of how a preventive environmental protection strategy within industry can result in substantial savings (Lidgren, 1993). Effective management of industrial waste improves the competitiveness of a firm and ultimately, therefore, the material welfare of society and is thus a matter of clear societal concern.

The information situation deteriorates as a result of the prevailing lack of knowledge about waste management models, specifically in regard to the models that are used daily, and the way in which they work. The general knowledge of societal waste management models, in particular regarding corporate internal mechanisms, is thus less sufficient. The specific scientific problems regarding the currently used construction waste management models and the way they function can therefore be said to be:

- Lack of knowledge.
- The business economic management models that are used today are *not* in any way focused on the issue of (construction) waste management in particular.

These scientific problems imply the existence of a substantial potential for research in waste management modelling, which, it is hoped, will at least partly allay the environmental concerns raised from the current practices.

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1.7 Objectives

In order to achieve a clean enough environment, taking business economic considerations into account as well, industrial waste must as far as possible be eliminated. This requires a direct linking between the very existence of waste and company profits. Thereby, the objectives of this work are as follows:

1. To analyse how commonly known business economic theories, also in the Polluter-Pays Principle context, can be applied to waste management theory in general and to waste fractionation in particular in order to environmentally optimise industrial and construction waste fractionation, the two sub objectives being as follows:

   1.a) To further develop a foundation for a new way of looking at industrial waste presented earlier (Stenis, 2002). Therefore, the study is performed with the aim of analysing to what extent this new view on industrial waste can be applied to construction waste also.

   1.b) To partly present a new theory concept and partly present new data findings.

2. To contribute to an improvement in societal resource economy. In doing so, the intention is to inter alia theoretically describe and evaluate certain common economic models that have a potential to be useful in a waste management perspective, and to discuss how these models can be adapted to waste management circumstances and needs, the four sub objectives being as follows:

   2.a) To present suggestions of how commonly known business economic cost-revenue theories and contribution margin theories, and also PPP, can be applied to waste management theory in general and to waste fractionation in particular, in order to environmentally optimise industrial waste fraction separation by enabling the use of regulatory (economic) instruments.

   2.b) To suggest basic business economic principles as a basis for further elaboration of, for example, environmentally friendly waste management recommendations and/or voluntary environmental agreements.

   2.c) To suggest how the companies that produce waste should allocate environmental costs to this waste in compliance with the PPP and the ambitions as stated at the Rio de Janeiro top summit in 1992, The United Nations Conference on Environment and Development (UNCED).

   2.d) To investigate certain aspects of construction waste management through case studies. Thereby, the applicability of the current modification of the above mentioned business economic models in a construction waste management perspective is tested. Generally, the strategy is directed towards development of flexible management instruments adapted to changing societal demands.

1.8 Delimitations

As regards the physical relationships involved, the work deals with industrial and construction waste only, municipal waste and hazardous waste, specifically, being outside the scope of the work. The definition of the very term "(industrial) waste" here reads as follows: "Material that has been paid for, which has not been turned into a marketable product." (modified after the definition of Jasch, 1996).

The general principles for evaluating industrial waste that are suggested in the work can provide the basis for further developments of business economic estimation and accounting practices within this area. This can result in practices being established that genuinely reflect the idea of a sustainable development.

The economic models that are modified mainly belong to the short run category for daily, operative use. A common economic theory such as cost-benefit analysis, intended for use on the long term basis, is regarded to have a primarily strategic character. Specifically cost-benefit analysis, applied in the long view, together with other models of a strategic, long run kind, is thus excluded from the review of the models adapted to short run economic waste management.

The bibliography referred to here provide the theoretical basis for the development of theory necessary as a foundation to build further on. This building is done in order to develop improved and novel theories within the current field of science.

The results in this work are not limited to consisting solely of mathematically exact economic methods for final use because business economics, as a scientific discipline, is generally being regarded as having a nature of constant compromises between different goals. This is so since "the terminology of costs is in a state of much confusion and (that) it is impossible to solve this confusion by discovering and adopting the one correct usage, because there is no one correct usage, usage being governed by the varying needs of varying business situations and problems. In other words, we are seeking to study the true nature of costs, about which actual cost-accounting systems give only an approximation." (Clark, 1923).

Joint production theory is disregarded in the aspiration to compare industrial and construction waste. This approach is namely designed for joint industrial production of products and wastes where inputs and outputs are expressed in a profit function to be maximised subject to technological restrictions (Paper V). The joint production approach cannot be applied to a construction object since this is largely being paid for by a number of larger parts comprising many construction components; allocation of the exact per unit profits to the waste is thus very difficult. Also, the erection of a construction object cannot be expected to mainly satisfy the wish to maximise the profit of the wastes that occur.

The EUROPE model, represents a totally different approach to the problem of controlling the growth of waste mountains as compared to management devices such as accounting, budgeting, operations research and environmental standards such as e.g. ISO 14001 and EMAS. In 1996, ISO 14001 was declared to be an international standard, replacing all previous national standards. In the waste management context, this leads to a corporate environmental ambition to apply preventive measures and, from a business economic point of view, the ambition is to implement "the best available technology" (BAT). In doing this, the objective is to ensure a continuously diminishing impact on nature (Jörnlid, 1996). The

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equality principle is instead aimed at influencing the very core of the company accounting system in order to force companies, for financial reasons, to take preventive actions to meet environmental standards. Therefore, the connection between international environmental standards and the work presented here is very weak. This fact justifies the exclusion of, for example, ISO 14001 and EMAS from the current discussion.

To a large extent, the research in this work deals with that takes place within the "black box" of the industrial plant or site in question. This implies that the findings in this work have a rather weak connection to the concept of producer responsibility, this approach mainly dealing with that takes place *after* that the industrial goods has left the "black box".

As regards the establishment of voluntary environmental agreements, an approach recommended on a large scale by the European Commission, the geographical area addressed in this work is primarily that of Europe in general and the European Union in particular.

Generally, the concept of voluntary environmental agreements is regarded as a viable alternative to traditional instruments such as environmental fees and taxes. In light of this, such fees and taxes are excluded from the theoretical description; the concept of the equality principle has been studied as an alternative to environmental fees and taxes for environmental management.

The stakeholders aimed at in writing this thesis are partly the academic community, i.e. the academic colleagues of the author and partly the managers and technicians in industry. This is regarded suitable because of the theoretical review provided here that is only partly adapted to final, practical, daily use in industry.

Aspects of a pedagogic nature are not considered. The acceptability of the theory and its firm establishment among citizens are to be studied in another work. The same reasoning is applicable to safety issues.

This work claims to cover the use of industrial waste management models in companies considering the stated provisos as regards societal aspects that are encapsulated in the work as well. The societal and corporate system limit of the thesis can be illustrated schematically as shown in Fig. 1.2.
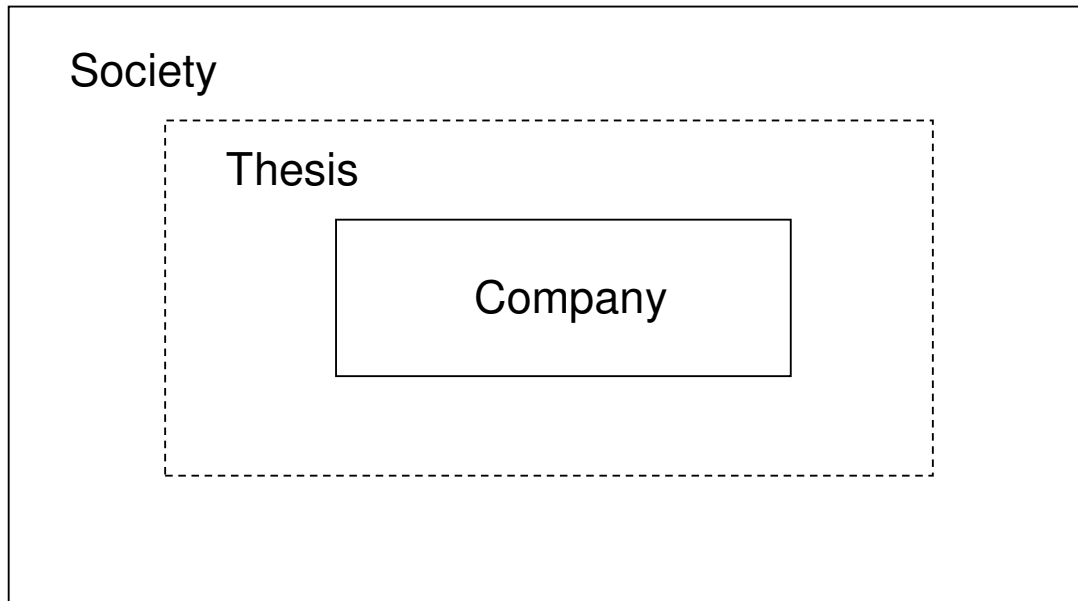
Figure 1.2. Thesis system limit as regards consideration of societal and corporate aspects.

1.9 Nomenclature

1.9.1 General nomenclature

Some key terms used in this work are explained below.[1]

Classification of waste - the arrangement of sorting waste materials into uniform categories of classes, usually by size, weight, colour, material etc.

Clean production - a concept of industrial production that minimises all environmental impacts through careful management of resources use and of product design and use, systematic avoidance and management of residues, safe working practices and industrial safety.

Clean products - products that are considered to have a minimal negative impact on human health and the environment.

Clean technologies - production processes or equipment with a low rate of waste production. Treatment or recycling plants are not classed as clean technologies.

Collection of waste - the act of picking up waste materials from houses, businesses or industrial sites and hauling them to a facility for further processing, transfer or disposal.

Commercial waste - waste from shops, offices, businesses and places of employment.

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[1] The explanations of waste related terms come from *1000 terms in solid waste management* (Skitt, 1992) and *Glossary of useful terms* (Lunde, 1993). The explanations of management related terms come from *Business, 25.000 words and phrases (*Swedish *Business, 25.000 ord och fraser)*, (Norstedts, 1995).

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Compost - organic matter decomposed aerobically and used as a fertiliser or soil conditioner.

Composting - a biological process in which the organic material in the waste is converted into a more stable material by the action of micro organisms already present in the waste.

Cost benefit evaluation - a comparison of the costs of any proposed project or undertaking with the value of benefits that would be expected to follow from the implementation of that project or undertaking.

Ecology - the study of the inter-relation between living organisms and their environment.

Emission - a material that is expelled or released to the environment.

Energy recovery - a form of resource recovery in which the combustible fraction of waste is converted to some form of usable energy.

Environment - all the surroundings of an organism, including other living things, climate and soil etc. In other words, the conditions for development or growth.

Environmentally friendly - an imprecise term used to describe a product whose manufacture, use and disposal is considered to have a minimal negative impact on human health and the environment.

Hazardous waste management - the control and management of the storage, separation, collection, transportation, processing, treatment, recovery and disposal of hazardous waste.

Industrial waste - waste from any factory or industry.

Integrated waste management - the term refers to the complementary use of a variety of waste management practices to safely and effectively handle the municipal solid waste stream with the least adverse impact on human health and the environment. An integrated waste management system will contain some or all of the following components: source reduction, recycling of materials, waste combustion and land filling.

Landfill - the deposit of waste onto and into land in such a way that pollution or harm to the environment is prevented and, through restoration, to provide land that may be used for another purpose.

Manage *vb.* - to direct or to be in charge of (Swedish: sköta, leda)

Management *subst.* - directing or running a business (Swedish: ledning, förvaltning, företagsledning).

Manager - head of a department in a company (Swedish: avdelningschef).

Municipal solid wastes (MSW) - the refuse materials collected from urban areas in the form of organic matter, glass, plastics, waste paper etc, not including human wastes.

Non-renewable resources - materials that are not readily replaced naturally. Their use depletes future availability. Examples of these are metals and fossil fuels.

Polluter-Pays Principle (PPP) - a concept that the person or body who or which causes pollution should pay for the neutralisation of the pollutant or the pollution. The concept implies that neutralisation of pollution and its effects should not be paid from the public purse.

Pollution - the addition of materials or energy to an existing environmental system to the extent that undesirable changes are produced directly or indirectly in that system.

Re-use - the further use of waste materials in their original form after repair or modification.

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Reclamation - the restoration to usefulness or productivity of materials found in the waste stream. Reclaimed materials may be used for purposes different from their original use (Swedish: upparbetning).

Recovery - the collection and processing of materials prior to despatch for recycling (Swedish: deproduktion).

Recycling - the reuse of materials, not necessarily in their original forms (Swedish: återvinning).

Renewable resources - materials that can be readily renewed by natural means.

Separation - the systematic division of solid waste into designated categories.

Solid waste - any refuse, certain sludges and other discarded materials, including solid and semi-solid materials resulting from industrial, commercial, mining, agricultural operations and domestic activities.

Solid waste management - the purposeful, systematic control of the generation, storage, collection, transport, separation, processing, recycling, recovery and disposal of solid wastes.

Source separation - the setting aside of recyclable waste material at the point of generation or collection.

Sustainable development - development that can be sustained in terms of economics. The term may mark the degree or level of development that is economically viable. Alternatively: processes that can be maintained by natural restorative means.

Toxic (toxicity) - a substance or material which, when taken in, produces a detrimental effect on human, animal or plant life.

Treatment - any method, technique or process, including neutralisation, designed to change the physical, chemical or biological character or composition of any waste so as to neutralise such waste, or so as to recover energy or material resources from the waste, or so as to render such waste non-hazardous or less hazardous; safer to transport, store or dispose of; or amenable for recovery, amenable for storage or reduced in volume.

Waste - waste is generally defined as that which is discarded as superfluous and has no further use or value to its owner. Definitions of legalistic/authoritative bodies are variable: United States Environmental Protection agency (EPA): Unwanted materials left over from a manufacturing process; United Kingdom Control of Pollution Act 1974: Any substance which constitutes a scrap material or an effluent or other unwanted surplus substance arising from the application of any process; EC: Any substance or object which the holder discards or intends or is required to discard.

Waste disposal - the process of getting rid of unwanted, broken, worn out, contaminated or spoiled materials in an orderly, regulated fashion.

Waste minimisation - the reduction of waste by the limiting of packaging by weight or volume or by making materials recyclable to avoid them entering the waste system.

Waste reduction - the prevention of waste at its source, either by redesigning products or by otherwise changing societal patterns of production and consumption.

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1.9.2 Nomenclature specific to some of the novelties in the present work

Some key terms invented during the course of the licentiate and doctoral works of the author are explained below.

The equality principle – the equation of industrial waste with normal industrial products in terms of the allocation of revenues and costs.

The model for Efficient Use of Resources for Optimal Production Economy (EUROPE) – the mathematical representation of the equality principle expressing the suggestion of the author that the waste fractions studied should be regarded as a kind of industrial product output.

Industrial waste – material that has been paid for, which has not been turned into a marketable product (Stenis, 2002) (modified after the definition of Jasch, 1996.)

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2 Methodology

This chapter presents the different components in the build-up of the methodology framework that the study is based on, the methodology is considered to be "the principles of method" leading to the "methods" in the form of the specific approaches adopted (Checkland and Scholes, 2001). The presentation is divided into two major parts. First, the general methodology applied in the work is reviewed. Then, the methodology for the investigations that are conducted is reviewed. Finally, the overall work organisation is presented. The methodology described in Stenis (2002) was used here to a certain extent.

2.1 General methodology and theoretical background

This sub chapter gives the theoretical methodology basis for the general methodology used in this work.

2.1.1 The author's reference framework

Due to his Master of Science in Engineering degree, the author has a strong interest and involvement both in technology generally and in industrial economics. In the course of his licentiate work (Stenis, 2002), he also obtained a Bachelors' degree in Business Administration. In line with the attention devoted to the waste management question by such organisations as the UN and the EU, the author found it to be a natural choice for his licentiate and subsequent work to conduct studies of industrial and construction waste management. This effort has resulted in the present work, which it is hoped can contribute to fulfilling the author's ambition concerning industrial waste management so to best further an environmentally friendly and economically profitable approach to industrial and construction waste management.

2.1.2 Scientific outlook

The intention of the study, inter alia, is to present economic models, primarily for short run use, as objects for modifications with the ambition to provide initial outlines of how to make them adapted to mainly practical daily use in waste management. Therefore, it is intended to provide suggestions of how these models can be modified, in particular so as to be able to estimate the "full" cost of industrial waste fractions in the light of the equality principle introduced earlier (Stenis, 2002) as a basis, for example for official recommendations and requirements and voluntary environmental agreements regarding waste.

The problem has been analysed from a corporate strategic perspective to a large extent. A research approach aimed at creating modifications of theories and models is thus applied. The ambition in this context is thus to move the research frontier ahead within a rather limited area by the use of rather few parameters.

Another intention of the study is to present an overview of certain relevant application possibilities for economic model theory as regards construction waste. The tool that is used to obtain the information is case study technique.

2.1.3 Discussion of method choice

2.1.3.1 The research design

According to Andersson and Borgbrant (2000) there exist mainly four categories of research design. They are as follows:

1. Change (many parameters)
The research problem is centred on measures - What should be changed and how? - and the choice of method is centred on participation of stakeholders through case studies. Data is gathered through dialogue with questions and the results consist of increased knowledge about change processes that is presented at e.g. seminars.

2. Evaluation (many parameters)
The research problem is centred on mapping - What characterises the object of study? - and the choice of method is centred around investigations through examinations. Data is gathered through inquiries with interviews and the results consist of increased knowledge about the phenomena studied that is presented in internal and external reports.

3. Development of theories and models (few parameters)
The research problem is centred around knowledge build up and the choice of method is centred on expert and specialist studies. Data is gathered through study of literary sources and the results consist of systematic documentation of the elaborated conceptions, theories and models that are presented in e.g. articles and papers.

4. Test (very few parameters)
The research problem is centred on hypotheses - What is characteristic for a specific function? - and the choice of method is centred on laboratory investigations through experiments. Data is gathered through measurements and/or simulations and the results consist of facts about an object and its qualities with respect to the value of the variables investigated that are presented in scientific papers.

Description of how the research design theory was used in the present work

Considering the presentation above, it is observed that the character of the study at hand is partly consistent with the research design concept "development of theories and models", which constitutes the formalised design foundation of the research project endeavoured with respect to modification of economic models. The character of the study at hand is also partly consistent with the research design concept "change" with respect to the investigation through case studies.

2.1.3.2 The research approaches

A description of the prevailing business methodology related approaches is presented below as a basis for the following discussion.

1. Analytical approach
In this, the oldest approach of the three described here, the whole is the sum of the parts. Therefore, the knowledge developed is independent of the individual and independent of subjective experiences. Also, the parts are explained based on verified judgements about a reality that is considered to be objective. Theory and methods given in advance enable verification or falsification of the elaborated hypotheses. Consequences are explained by an attempt to find the causes enabling a *ceteris paribus* reasoning. It is a prerequisite for continued accumulation of knowledge that the results obtained can be generalised. In an analytical cycle, one starts with empirical facts and observations, induces theories and deduces predictions in order to obtain new facts that hopefully are verified.

2. Systems approach
During the 1950s, systems theory emerged, inter alia as a reaction against the summarised picture of reality inherent in the analytical approach. Systems theory today dominates business economic thinking in Scandinavia (Arbnor and Bjerke, 1994). In this approach, the whole is *not* the sum of the parts since the relations between the parts are important. Therefore, the knowledge developed is systems dependent. Also, the parts and individuals in question are explained or understood based on the qualities of the whole. Reality is considered to be objectively available. A prerequisite for the acquisition of knowledge is analogies. Consequences are explained by an attempt to find an appropriate driving force. Since synergy effects are assumed to exist, the results consist of typical cases and certain general classification mechanisms, sometimes enabling to a certain extent unique cases. Instead of cause and consequence-relations, one uses indicator and consequence-relations enabling the "cause" to sometimes follow the "consequence" in time. It is precisely the hidden and intermediate factors which are the quality of the relation, looked for in order to achieve a better picture of the system and possible synergy effects inherent in the systems relations.

3. Actor approach
This approach emerged at the end of the 1960s. It claims that the whole can be understood based on the qualities of the parts. Actor theory does not intend to explain, but tries to help the understanding of the social entirety from an individual actor perspective. The approach focuses on mapping the importance and the meaning that different actors put in their actions and the surrounding environment. Therefore, reality is assumed to be a social construction that is intentionally created on different meaning structured levels. This implies that our common language has a different meaning depending on the level. The whole and the parts have multiple meanings and are continuously reinterpreted. Systems qualities are not relevant for the understanding of organisations, businesses and companies. Instead, interest should be directed towards the actions of actors that are important in a social context. An organisation cannot be said to act itself, but the different individual actors act. Hence, systems do not exist in the systems theoretical meaning. Actor theory namely claims that systems are owned by the knowledge seeker and his systems theory, and is therefore not based on how the actors interpret themselves in relation to their own experienced and constructed meaning structured entireties. Therefore, the knowledge developed is dependent on the individual. The dialogue is used as the basis for the dialectic process based on the thesis that creates its antithesis

leading to the synthesis. Also, diagnosis is used to understand and interpret actors and situations to develop tools for improved self-understanding and guidance in future acting (Arbnor and Bjerke, 1994).

A normative model is often based on analytically clear-cut ideas about how decisions should be taken while a descriptive model describes how decisions are taken in reality. A normative model for decisions (or for investigation and research purposes) can look as follows:

Goal $\longrightarrow$ Alternatives $\longrightarrow$ Evaluation $\longrightarrow$ Decision

Rational decisions taken in this way require unlikely assumptions: the decision-making takes place in just this order; the different steps can be separated and defined unambiguously etcetera. Of course this is very difficult in practice. A descriptive decision model takes this into account. Reality is seen in quite different ways depending on whether the approach is normative or descriptive (Wiedersheim-Paul and Eriksson, 1991).

<u>Description of how the research approach theory was used in the present work</u>

Hence, an analytical, normative model approach is used here to a certain extent. In the process of the waste adapted modification of the mainly short run economic models, primarily an analytical economic-logic approach is thus applied. However, in discussing the functionality of the modified models arrived at, descriptive systems theory is applied in order to get a clear picture of the models' societal context. The individual perspective is not very prominent in this work that does not place much emphasis on social factors as explanatory variables. Therefore, the actor theory approach does not play a role here in that it emphasises personal aspects and assumes reality to be mainly a social construction.

2.1.3.3 The research process

Generally, the research approach of this thesis is more positivistic than e.g. humanistic hermeneutics that is aimed at interpretation and understanding of primarily social phenomena based on also the personal values and experiences of the scientist in question in a holistic perspective (Lundahl and Skärvad, 1992). The humanistic hermeneutics view, therefore, is less applicable to the present model oriented and non-personal thesis approach chosen. However, in applying a system approach, one takes a holistic rather than a reductive perspective on the problem, the system being more than its separate parts (Checkland, 1993). According to Lundahl and Skärvad (1992), the research process of the positivistic methodology goes through the following stages:

1. Reality is observed and facts about it are collected.
2. Enough facts make it possible to see patterns and regularities in reality; this may lead to general conclusions.
3. The science grows through the collection of ever more facts, enabling ever more bigger and general conclusions to be drawn.

More specifically, the positivistic research process consists of the following elements:

1. A phenomenon that seems to follow a consistent pattern is observed.
2. A large sample of data is collected in order to investigate if consistency can be found also in this large sample material.
3. A theory is developed to explain the phenomena - induction.
4. The implications of the theory are used to make predictions - deduction.
5. The predictions are tested. Do the consequences that are predicted occur?
6. Identification of the differences between observations and the predictions - verification or falsification. A good theory shows a high consistency between the predictions made and the current outcome.

Description of how the research process theory was used in the present work

This procedure is to a large extent consistent with the approach of this work - even though case studies are performed - which is briefly described below from a more practical point of view in order to make it possible, to a certain degree, to repeat the study.

1. The importance of applying economic models in a construction waste management perspective, consistent with the objectives presented here, is recognised according to a pattern that is observed pointing in the direction of an important need to be considered.
2. Relevant information is collected to investigate the existence of consistency with respect to the pattern observed. In particular, information is obtained about corporate waste management by short run models plus construction waste management in practice as well.
3. A prediction is deduced for the applicability of existing cost-revenue estimation methods, also in the PPP context, to the construction industry preventive waste management area through method modifications.
4. Explanatory theory attempts are induced in order to achieve waste management applicability for the economic models and other relevant theories that are studied.
5. The current economic methods are studied from a waste management adaptation through modification perspective. Case studies are also performed inter alia within the framework of the papers appended to support the theory build up.
6. The economic method modifications arrived at are evaluated within the framework of the papers appended.
7. An attempt is made to "describe and establish connections" as a part of a resulting "IS-mode" and to "predict and guide" as a part of a discussing "SHOULD BE-mode".
8. The prediction is tested based on the implications of the theories that are induced through discussions over the waste management aspects of, inter alia, the managerial context. In this case, the overall prediction is partly verified, or rather partly reasonably justified, partly based on the conclusions reached in the appended papers.

2.1.3.4 Graphical illustration of research

The present research project follows the principle shown in Fig. 2.1, this work constituting one major part of the overall methodology. The first six stages represent the theoretical foundation of the theory build-up developed in the present work. As shown in Fig. 2.1, this work deals mainly with the stages four to seven. The first two stages aim to create a picture of the situation where there is a perceived problem identifying how structures and processes relate to each other (Checkland, 1993). In the third stage, the different structures and

processes are formed as a relevant system, which is developed with reference to the perceived industrial construction waste management problems with their related causes.

By comparing the system to other system concepts, conceptual models of solutions to the perceived problems are created in stage four. Analytical, partly real world, thinking for the economic method modifications is another input to the creation of conceptual models.

In the fifth stage, a comparison with the real world takes place. The outcome is then a basis for a sixth stage analysis of the suitable changes that are considered necessary to carry out in order to realise the sustainable ideal in practice within industry. In this research project, more emphasis is put on this stage, together with a stage seven extension concerning what concrete actions to take in order to improve the problem situation that is represented by the current statements and recommendations of the author.

The theoretical design of the models follows the principle shown in Fig. 2.2. The construction process of the models presented in this research is coloured throughout by the author's reference framework. The more formal framework for the whole of the research is represented by the specification of: a) the design; b) the approach and; c) the process for the research. These three items are mainly characterised by: a) "development of theories and models" plus "change"; b) "the analytical normative model" plus "descriptive systems theory" and; c) "positivistic research approach". The factual academic theoretical background for the formulation of the model inventions of the present research project mainly consists of the author's academic degrees, other education and competence within general: a) business economic theory; b) waste management theory and; c) environmental management theory. These three components, plus what is mentioned earlier form the basis for the innovative formulation of: a) the equality principle and; b) the EUROPE model. This model, in combination with the theory of cost-benefit analysis (CBA), contribution margin analysis (CMA) and the Polluter-Pays Principle (PPP), constitutes the theoretical basis for the four new papers presented in this thesis. Paper IV and Paper V are mainly based on general business economics theory, waste management theory and environmental management theory. However, the equality principle forms the ideological basis, in an environmentally related sense, for the elaboration of the mathematically directed theory in the paper concerning joint production (Paper V) encompassing linear programming theory as well. Generally, the licentiate dissertation represents the scientific, theoretical basis for the present work, although the basic concept of, for example, the equality principle is substantially more elaborated upon and developed further in this work. Papers I, II and III, together with the case study, block Opus 1 in Paper VI, mainly form the common foundation for the general statements related to industrial and construction waste management models made in the present work. Finally, Paper VI represents mainly the changes in waste management views that are proposed by the author.

2.1.4 Overall prediction

In this work, a prediction is formulated. Usually, an investigation is of a deductive character when the scientist, through the formulation of the problem in question as a hypothesis, wants to investigate whether the empirical consequences derived from a theory are consistent with the actual situation (Halvorsen, 1992). This is partly the case here where an overall prediction is tested and found to be partly reasonably justified, even though not at all undoubtedly verified. This is so since, when the possibilities of proving a theory beyond doubt are small,

one has to restrict the ambition to showing whether a prediction or a theory is more or less justified or not (Knutsson, 1998). In this work, the waste management adapted alterations of specifically the economic methods considered are deduced as a kind of a first step mathematical solution to the problem described to be further elaborated, and are summed up in an overall prediction to be verified/justified or falsified.

Within the framework of the basic problem described, the overall prediction to be considered can be formulated as follows: Existing cost-benefit estimation methods, as well as PPP, *can* be modified so as to make them practically applicable to the industrial and construction preventive waste management area. They can provide a basis for both official recommendations and requirements and voluntary environmental agreements concerning environmentally friendly industrial construction waste management. Such agreements can serve as viable alternatives to traditional approaches based on taxation and the use of fees. A change in attitudes towards industrial and construction waste and the promoting of investments in profit-enhancing production processes that utilise waste in an environmentally friendly way can thus be achieved.

2.1.5 Gathering of information

The *sources of information* on which the work is based, in addition to relevant literature and articles, have included information obtained through database search, the Internet, questionnaires and personal interviews with people working daily in industry as well as with academics. Data in the literature used is processed, thus making it secondary data since primary data is new and unprocessed data. According to Arbnor and Bjerke (1994) there exist two problems with the use of secondary data:

1. Compatibility. Previously collected or secondary material might have been collected for another purpose. Existing data may therefore be classified differently or start from a different measurement scale and/or from other definitions.
2. Trustworthiness. Researchers may be uncertain about the extent to which previously collected data are correct.

The use of secondary data requires a certain caution, but secondary data is most useful in reflecting the surrounding environment and the related systems (Arbnor and Bjerke, 1994). In this study, one of the major objectives is to show how commonly known business economic theories can be applied to waste management theory needs. Therefore, it is necessary to use secondary material literature extensively in order to gather relevant economic theory findings in a reasonable amount of time.

This will cause some problems in validating the results and assessing their reliability. It can be argued that this is cared for in the present project when the models that are elaborated are compared with the real world to a great extent. If the models then do fit to the real world conditions, one of the reasons may be that the literature used has been compatible or trustworthy.

Primary data that has to be collected was however obtained during the course of the case studies. The case studies were directed towards Swedish industry.

7. Action to improve the problem
situation

The present
study

1. Unstructured
problem
situation

6. Feasible
desirable changes

Stenis (2002)

2. Structured
problem
situation

4.b Analytical
thinking.
Case studies

5. Comparison
of 2 and 4

Real world

3. Root definition
of relevant
systems

4. Conceptual
models

System thinking

4.a Formal
system
koncept
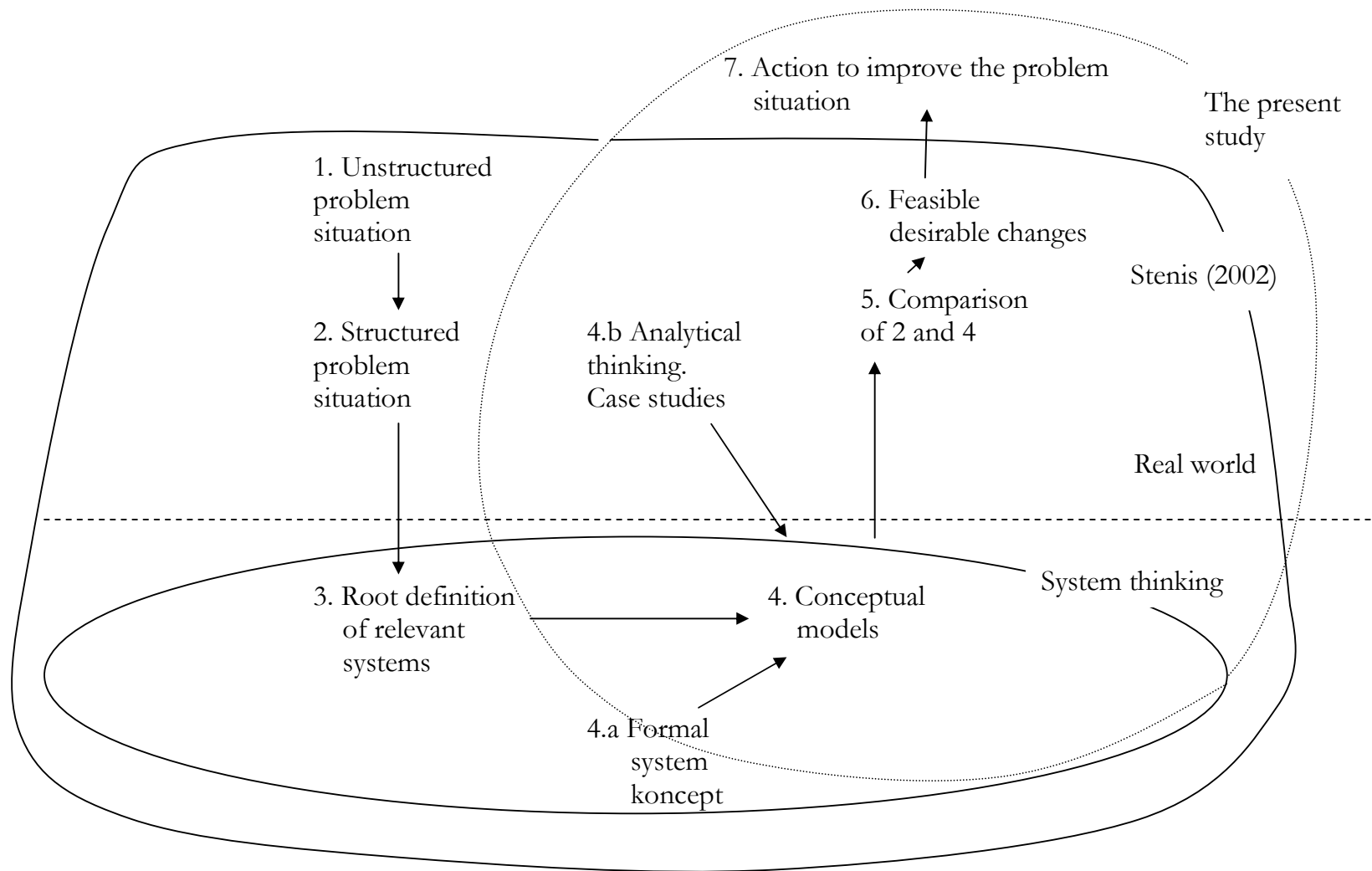
Figure 2.1. Principle framework of the present research project methodology (adapted from Checkland, 1993).

The author's reference framework

Research design	Research approach	Research process

General business economic theory	General waste management theory	General environment management theory

The equality principle

The EUROPE model

CBA	CMA	PPP	LP

Paper I	Paper II	Paper III	Paper V	Paper IV

Paper VI. Case study block Opus 1

Dr thesis papers

Licentiate dissertation papers

- General industrial waste management Dr thesis model statement
- Construction waste management Dr thesis model statement

Figure 2.2. Principle of the theoretical model construction in the present research project.

2.1.6 Qualitative research methodology

2.1.6.1 Qualitative research

Qualitative methodology is characterised by closeness to the studied object. There is a direct subject-to-subject relation between the scientist and the investigated unit. Qualitative methodology thus represents a trying to bridge the subject – object relationship that is typical of the natural sciences.

Through the closeness between the scientist and the investigated object, the whole situation is patterned by the own behaviour. Some general principles as advice regarding how to conduct such investigations are outlined below (Magne Holme and Krohn Solvang, 1991):

- Closeness to the investigated objects; socialisation and mutual trust must be developed.
- The description of the passing of events must be real and true according to the scientist's objective view.
- The report should consist of only descriptive descriptions in proportion to the need for understanding of the relationships investigated.
- In order to reach the best result possible, the report should contain direct quotations showing the individuals own way of expressing themselves (both in writing and orally).

When applying qualitative methodology, it is less important than when applying quantitative methodology to know how representative the current information is, if one has measured what was intended to measure and if the collected information is reliable. This is so since the main purpose with a qualitative study is to achieve a better understanding of certain factors, this not putting the statistical representativity in focus. It is practically impossible to combine this with an in depth study of the studied person's experiences and self-awareness. This fact reduces the problem to acquire valid information since the closeness to the studied object is much less than when conducting a qualitative study. However, the closeness can sometimes be a problem as a result of the creation of certain expectations of certain behaviour. Therefore, the scientist must as much as possible try to reach the personal views. Entering the role as the interested listener favourably does this.

2.1.6.2 Qualitative methodology interview

Usually a distinction is made between *informator interviews* and *respondent interviews*. The former is used when the very persons of interest are not possible to reach while in the latter case the objects of interest are interviewed directly.

2.1.6.3 Qualitative interview textual information

When a qualitative interview is performed, all structuring and organisation of the information must take place after that the gathering of information is ended. It is recommended to use a tape recorder to have a basis for the writing down of the interview. The out prints can be sent to the interviewed person and the tape recording can be attached. By this the respondent can check if his answers are registered correctly and make comments on the text. Generally, personal expressions should be kept but it must not be possible to identify the respondent.

The latter principle of analysis of the parts is based on the comprehension that the out prints is a text in itself that encompasses statements about a number of phenomena which are more or less connected to the phenomenon that is in focus for the investigation. The statements can be categorised or described in the form of tables. The units in the analysis will be words or statements in the text, which then are grouped into the different categories. Through the analysis, one then, based on these single statements, constructs an interpretation about the phenomenon one is investigating.

2.1.6.4 Observation

The term "observation" is here defined as to for a longer or shorter period be together with (or be in the closeness of) the members of the group one is to investigate (Magne Holme and Krohn Solvang, 1991). Observation implies that one is confronted with a number of choices, which in many cases have ethical repercussions.

The role as an observer can be designed in many different ways. A major crossroad in this context is whether to observe openly or hidden. *Open observation* is defined as an investigation where the participants know and have accepted that one is observing them. This kind of role gives the investigator a large amount of freedom since he is expected to fulfil the expectations of an observer. *Hidden observation* is split into two versions; either there is no direct contact with the actors, or the investigator participates in the group that is studied but no one knows that one is conducting an investigation. In the latter case, it is important for the observer to be accepted by the group and encounter its trust.

2.1.6.5 Study of original sources

A "source" is defined here as "material that is written down" (Magne Holme and Krohn Solvang, 1991). Sources can be normative (valuing) and/or cognitive (relating), oriented towards the past or the future, confidential or public, personal or institutional. It can be a primary or a secondary source and it can be a first hand source or a second hand source. Usually the different categories are overlapping.

The very study of the original sources is split into the following four stages: 1) observation of sources; 2) determination of the origin of the sources – who is behind it and from when is it?; 3) interpretation of the sources, i.e. to determine the contents of the sources as regards the intention of the originator of the source and 4) determination of the usefulness of the source as regards the intended purposes for the investigation based mainly on the originators' credibility.

2.1.6.6 Description of how the qualitative research methodology theory was used in the present work

The closeness to the studied object that characterises the qualitative research methodology is represented in the present work by the direct contact with, for example, the representatives of industry and construction industry who were interviewed. This direct subject-to-subject relation with open observation between the scientist and his object of study had the aim of achieving a better understanding of certain factors, without focusing on the statistical representativity. This approach, the field interview, has the advantage of involving a mutual sharing of experiences as the researcher encourages and guides a process of mutual discovery (Neuman, 1999).

However, both informator interviews and respondent interviews were used depending on the current availability of the interviewed persons. Practically, when conducting the respondent interviews, a tape recorder was used to have a basis for transcribing the interview. Using machine recordings has the advantage of providing a close approximation to what actually occurred since this provides a permanent record that others can review (Neuman, 1999).

Thus, standardised forms were not used when the qualitative interviews were conducted. This was so since too much control from the author was not wanted in order to make the points of view that were registered to be a result of the own points of view of the investigated persons. Instead the respondents were allowed to as much as possible manage the interviews themselves. Thus, giving the respondents a large amount of freedom was deliberate. However, a manual for the interview as a guide for the conversation specially prepared for the project was given to the respondents.

Generally, the information in the case studies is based on public and personal first hand sources but also on both primary and secondary sources as regards textual material. To a certain extent, the different categories are overlapping.

2.1.7 Quantitative research methodology

2.1.7.1 Quantitative research

Historically, quantitative research methodology is based on the comprehension of ideal science being unbiased and objective (Magne Holme and Krohn Solvang, 1991). This is mirrored in the planning of the science. Ideally, the scientist should be a detached observer and not be a part of the studied object himself. However, the scientist is not and cannot be free of valuations and totally objective. He is a human being and it is himself, not anybody else that takes upon himself the role as a scientist.

2.1.7.2 From theory to empiri

The passing from theory to empiri constitutes a critical phase in the investigation. Even though the scientist has made an *operationalisation* of his theoretical starting-points, which he regards to be all covering, and fruitful, he cannot, based on the operationalisation, be sure that the studied persons are of the same opinion.

A conception can be defined in different ways. *A distinguishing definition* describes the qualities of the conception. In *an enumerating definition*, the contents - e.g. municipalities of interest – of the definition is enumerated. *An exemplifying definition* describes a group by conditions that are characteristic for the unit that is to be defined.

2.1.7.3 Gathering of information

What information to gather is totally decided through the question at issue. That and the formulation of the problem should clarify the units in the survey and what qualities at the units that one wants to get information about. Generally, it is important to document the information retrieval in order to make it possible for others to repeat the study.

2.1.7.4 Going from raw data to processed information

The notes, recording and other registrations the scientist does in a survey are the unprocessed information or raw data, i.e. the disordered information. The information can be analysed through computer processing. However, the quality of the result depends on the quality of the unprocessed information regardless of the use of computers or not.

2.1.7.5 Analysis of information

Inquiry or analysis is usually thought of as the attempt to tell what are the characteristics, causes and/or consequences of a phenomenon, the form it assumes and the variations it displays (Lofland, 1971). This view is consistent with the ambition of the present work, the phenomenon at issue being industrial and construction waste management.

2.1.7.6 Interpretation of information

It cannot be guaranteed that a collected material is compatible with the views of the respondents. Nor can it be guaranteed that the scientist's understanding can be transferred to a broader audience. Hence, it is reasonable to talk about a communication gap between scientists and respondents, on one hand, and between scientists and receivers of research results on the other hand.

2.1.7.7 Description of how the quantitative research methodology theory was used in the present work

The objective detachment as regards the studied object that characterises the quantitative research methodology is represented in the present work by the processing of "neutral" numerical data mainly in the case studies. However, data, tables and computer output cannot answer research questions. The facts do not always speak for themselves. Therefore, the author of this work has returned to his own theory (i.e. concepts, relationships between concepts, assumptions and theoretical definitions etc.) which is that give the results meaning (Neuman, 1999).

The operationalisation in the present work consists partly of the nomenclature in 1.9, the conception being defined by mainly distinguishing definitions. Generally, the quantitative information used in this work is suitable for the object of study since it stems from well informed men who are daily working in the relevant companies of interest and stems from public information material plus, to a certain extent, highly relevant textbooks. Thus, in this

work, qualitative and quantitative research methodologies are combined. In doing this, advantage can be taken of the similarities between the approaches such as 1) the involvement of inference, i.e. reaching a conclusion based on evidence, 2) the collection, description and documentation, of data, 3) the comparison of features of the gathered evidence and finally, 4) the attempt to avoid drawing false conclusions (Neuman, 1999).

2.1.8 Validity and reliability

Generally, it is not appropriate to apply the terms validity and reliability in this context due to the systems approach chosen as the main approach to be applied here. However, the terminology is relevant regarding separate analytical tools, i.e. the methods developed here, which will, it is hoped, be applied in the corporate context. Such a validity and reliability review is presented below.

The *validity* of the methods developed here is evaluated by applying economic models, such as, for example, traditional cost benefit analysis methods and the contribution margin analysis method. These methods are appropriate to the aims of investigation since these methods are commonly accepted after many years of daily use in industry and are based on scientific results and long experience from its use in practice.

The *reliability* of the results is considered against the background of relevant textbooks and relevant case studies which provide a comprehensive review of relevant models commonly in use, in the past as well as today. Certain exceptions can exist, so that certain parts of the basic management theory are not considered.

2.1.9 Expected results and benefits

The ideas introduced here should be regarded as representing an approach which can be used, along with others, to establish a new era characterised by sustainable growth combined with reduced amounts of (construction) waste and decreased pollution. Hopefully, the work can induce a change in the status accorded to residual products and objects by emphasising the financial impact on costs, and also revenues, inherent in waste management theory.

The environmentally related instruments developed in the work are based on financial incentives and are thus economic instruments (EIs). An EI is highly compatible with voluntary environmental agreements between authorities and industry and other stakeholders, due to the emphasis put on company internal economic incentives. Therefore, the resulting tools developed can broaden the spectrum of relevant policy instruments and enforce the dialogue with industry and society in general on a more voluntary basis as well.

The equality principle introduced earlier (Stenis, 2002) is expected to have a substantial impact also on relevant profit and loss accounts, budgets and forecasts etc. Furthermore, the balance sheets are expected to be positively affected due to improved environmental waste related good will. Hence, a substantial financial incentive to behave in a way consistent with the ideal of long run sustainable development is created in a natural way due to the applications of the equality principle that are presented here.

Generally, the concept advocated here is considered to provide opportunities to efficiently contribute to preventing the common misuse of resources in society. In the long run, the result will be an overall improvement in the external environment, leading to an enhanced quality of life.

2.1.10 The presentation of the results

In the following, the mode of presentation of the results in the thesis is presented. First, the way that the results from the papers are presented is given followed by the way the results from the Block Opus 1 case study are presented.

2.1.10.1 Results from the appended papers

The results from the appended papers are presented under the "IS-mode" heading below. There, the outcome of the case studies is summarised in a systematic way.

2.1.10.2 Results from the case study block Opus 1

The results from the construction site case study are presented under the "IS-mode" heading below. There, the outcome of the Opus 1 study is summarised in a systematic way.

2.2 Case studies

This sub chapter gives the theoretical methodology basis for the description of the methodology applied for the case studies.

2.2.1 The case studies in the appended papers

Here is referred to the presentation in the appended papers.

2.2.2 The case study object Opus 1

In 3.2, the project is described as regards facts and figures for materials used, costs, construction principles and waste statistics etc. These facts are then analysed in 4.1 so as to provide a basis for the "Statement of the SHOULD BE-mode" following thereafter in 4.2. Thereby it is studied to what extent the equality principle introduced earlier (Stenis, 2002) is possible to apply on construction waste.

2.3 Overall work organisation

This sub chapter presents the overall design nature of the report followed by a description of the different forms of investigation used in the present work.

2.3.1 The design of the report

Scientific work is usually ended by a written report regardless of it is a research project, an investigation, a survey or an inquiry. As regards the disposition of the report, two models dominate. The first one is *the logical-historical model* that mainly follows the research process that contains inter alia background including objective, problem and theory, data collection, data processing, analysis and conclusions. The second one is called *the news-bill model* and is formed by the question: "What is interesting for the target group to know?" To simplify it, the news-bill model is the logical-historical model mirrored since it usually is the results that are of highest interest in a survey and come last in the logical-historical model. So far, the logical-historical disposition has been the typical model used in science. Probably, the time has not come yet for a change (Rosengren and Arvidson, 1992). This approach is also made reference to here.

Early in the research work, decisions are taken that anticipate and to a certain extent points out the way to go in the rest of the work. When one looks at the whole of a research project, one can limit the ways to go to a small number of main alternatives for the research design. These are: 1) explorative investigations 2) descriptive investigations, 3) explanative investigations, 4) survey investigations and 5) investigations for specific purposes.

Ideally, the presentation of the problem leads to the specified objective of the investigation. In an explanative investigation this is reviewed as one or many hypotheses that are to be tested. In descriptive investigation it is reviewed as information about what variables and parameters one wants to measure and assess in a certain population. In an explorative investigation, instead, one defines an area that is clearly delimited in which one tries to form relevant concepts or to define the "essence" of a phenomenon.

The next stage in the report writing is to present the material one has worked with in the empirical part of the investigation: data from interviews or inquiries and statistics etc. Thereafter, the results of the investigation are presented. The data that are acquired are presented, analysed and interpreted according to the presentation above. Usually, at the end of the report the results are summed up and discussed and further research is outlined. Good science is often said to lead to new and unexpected questions. Hereafter, the main alternatives for the research design are reviewed.

Explorative investigations

By a discovery should be understood knowledge about something that did not exist previously, i.e. explorative investigation knowledge, but the term is used also for new knowledge regardless of the level of knowledge. In particular, a "serendipity-discovery" is a shaking and important discovery of something that one did not look for at all and therefore lays outside the planned research work.

A scientist who wants to study a social phenomenon, with the purpose to understand its form and nature, must find it in its own world and on its own conditions. This takes place out in the field, out in society. One way of acquiring knowledge about the social phenomenon is to directly observe and experience it oneself. This can take place in the form of participation in a study. The other way is to make somebody to tell about it during a conversation or an interview. A third way, that often is a complement to participation in observation studies and to make interviews, is to use the different forms of documents that are written by the persons involved, e g. letters, diaries, protocols and journals etc. These three roads to follow, step by step are detaching themselves from the object of study.

The first problem that encounters the scientist in the field is to gain access to the social context in question. Thereby, the scientist must prepare the presentation of his issue, the role he is to play and what relations he is to have towards the other persons. Usually, it is advantageous to acquire a tutor who can tell about, interpret and explain what really is going on. It is necessary to write down and process that one has got to know and have experienced during the observing and questioning. The fieldwork is to be abandoned when no more new insights are gained and when more information only repeats what is already known. Finally, the research should be reported in written form.

Descriptive investigations

In a descriptive investigation the scientist looks for the existence, the extent and the spread of a phenomenon such as habits, behaviour, knowledge and attitudes etc. The scientist is expected to start from a good knowledge about the phenomenon in itself, i.e. he has a set up of conceptions and variables that capture the phenomenon in question. One wants to know how the relevant units are distributed along the variables that previous explorative research has shown.

The shift of attention from variables and concepts to population and units, results in that planning of descriptive research very much is about selection and representativity on one hand and instruments for measuring on the other hand. However, quantitative research is of primary interest, the most usual to perform being a descriptive investigation on a sample, a representative sub population.

Explanative investigations

The purpose with an explanative investigation is to investigate the causal relationship between two or more variables. *A causal relationship* means that a certain value for one variable gives a certain value on the other variable. The variable that affects the other variable is called *an independent variable*. The affected variable is called *a dependent variable*. A general problem when doing explanative investigations is to make a distinction between on the one hand statistical relationships (as described above) and on the other hand causal relationships.

A complete *experiment* is characterised by its giving opportunity to three kinds of operations: *manipulation* of the independent variable, *standardisation* so to make it possible to keep the circumstances of the experiment constant and to repeat them and finally *control* so to eliminate or measure the impact from a third or fourth variable on the correlation between two variables. Of course, a *laboratory experiment* gives the biggest possibilities to manipulation, standardisation and control, also in the case of sociological or psychological in

situ laboratory experiments. In an in situ *field experiment* the experiment takes place in "natural" surroundings. An example is PR campaigns for e.g. consumer goods.

Survey investigations

A survey investigation can be described as "a non experimental, random sample question investigation with a descriptive or explaining purpose" (Rosengren and Arvidson, 1992). In other terms, the survey investigation is non experimental, but if it is explanative the analysis of data can be said to be designed with the experiment as model. Generally, it is without manipulation and standardisation and has limited possibilities of control. This means no problems in a descriptive investigation. The question is how to conduct explanative investigations without manipulation and standardisation and with only limited possibilities of control.

Thereby, one tries to replace manipulation of the independent variable by different kinds of comparisons between groups that have different kind of values on the variable in question. The possibilities of control, above all randomisation, one tries to replace by different kinds of table analysis that aims at achieve the control of hidden and in between variables

Investigations for specific purposes

Two sub groups of investigations for specific purposes are the preparatory investigation and the investigation aiming at taking measures. *The preparatory investigation* is preparing the road for planned investigation work that is not yet planned in detail. The purpose is to lead to the forming of conceptions, questions and hypotheses in order to prepare another investigation that can be as good as possible. The start is usually *a literature survey* perhaps combined with *expert interviews*. *The case study* is a special form of preparatory investigations concentrated on individuals or other units. Also, there exists the *pilot study* as a test in the form of a miniature copy of a larger investigation conducted later in order to check that the investigation works purely technically (forms, selection, possibilities of control etc.) and in order to avoid trivial mistakes.

The investigation aiming at taking measures is designed to allow a work with practical means of actions to follow after that the investigation is finished and the results are published. Such investigations have a diagnostic purpose in order to come up with suitable actions. A common synonym is *programmatic investigation* as a part of a larger program of actions, a reform program or so. A third name is *diagnostic investigation*. Such efforts concentrate on variables that are possible to manipulate or are easier to change that other. In such cases, the question of which evaluations to highlight in the investigation is emphasised.

Action research goes one step further where the recommended actions are supposed to be implemented where after new investigations follow etc. By time, the term action research was reserved for investigations aiming at taking measures where the scientist explicitly takes side for the weaker part against the stronger part (Rosengren and Arvidson, 1992).

2.3.1.1 Description of how the theory for the different forms of investigation was used in the present work

Based on the review above, it is clear that the design of the work at hand is most consistent with the traditional logical-historical model due to its traditional layout as regards the scientific procedure that is used. The work can also be said to be mainly an exploratory investigation due to the study seeking new knowledge to present in written form.

2.3.2 Scientific levels of ambition

According to Arbnor and Bjerke (1994), the different forms of investigation can be divided into four different scientific levels of ambition:

- Describe
- Establish connections
- Predict
- Guide

In this work, "describe" and "establish connections" is part of the IS-mode while the SHOULD BE-mode, according to the view presented in this work, means to "predict" and "guide", in this case, to predict and design desired industrial waste management models. By defining the necessary pre-conditions for the transformation from the IS-mode to the SHOULD BE-mode, the company in question can be guided and achieve a basis for the introduction of the SHOULD BE-mode. In this work, the section "IS-mode" represents the results and the "SHOULD BE-mode" represents the discussion.

To a large extent, the work was carried out in co-operation with representatives from the companies that participated in the case studies. This is consistent with the long-term ambition within the Division of Construction Management at Lund University to carry out research project in close co-operation with private business companies. By this procedure, the chances are increased to partly conduct research useful for both parties and partly create preparedness in the companies to receive and adapt the scientific results. The present research project is an example of this.

In an investigation like this, both quantitative and qualitative research methodologies can be used, present examples being case studies. In order to inter alia get support with the finding of suitable potential objects for the case studies, a reference group was set up. The reference group consisted of three scientists from Lund Institute of Technology and one person from industry.

3 Waste management models – IS-mode

This chapter presents the very results from the appended papers and the case studies in order to making available to the reader a range of possibilities of developing industrial and construction waste management systems proposed in this study. Thereby, first the papers appended are summarised followed by a review of the construction site case study that was performed during the work. The chapters concerning economic models (Chapter 5 and Chapter 6), in Stenis (2002) have been found to be useful and are thus also used here to a certain extent.

3.1 Industrial waste management models

This sub chapter presents a summary of the results from the appended papers in a summarised way.

3.1.1 Prerequisites for application of the methods studied

Different possible scenarios are considered here. A particular waste fraction is studied within a given production scenario, one 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 then in assessing waste fraction *shadow prices*, producing an environmental improvement incentive. 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 a shadow price here is that if firms were actually charged the shadow price associated with pollution of some type, in reality they would take this into account. Such a financial burden would result in a pressure to meet the desired environmental standard for financial reasons. In any given scenario, therefore, a new assessment of revenues and losses is required for each fraction considered. The costs and revenues are estimated in a manner described below. The reviewed methods are as follows:

Table 3.1. 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
    6. Remainder method
II. Contribution margin analysis method
III.The Polluter-Pays Principle (PPP)

_____

In the next sections, different methods commonly used for estimating product costs are presented together with ways in which these methods can be adjusted, according to the view presented here. The ways these methods can be used to estimate the "true" internal costs of waste fractionation, are considered. The aim is to allocate costs to the waste produced this with the ultimate aim of maintaining and improving the environment. The underlying assumption is that from a business point of view a given waste fraction can be regarded as a kind of company product, one that should contribute to bearing the company's costs, just as the other products do. If it fails to do this, financial losses result, losses that need to be covered by surplus profit from other activities of the company.

Disposal of industrial waste often creates serious environmental problems. In the long run, these problems need to be eliminated, or markedly reduced, so that nature can be kept as clean as possible. This calls for the clarification and establishment of links between company profits, as expressed in consolidated profit and loss accounts, and both the avoidance and proper utilisation of waste. A new way of looking at waste, or, to a certain extent, a shift in views, is needed. Otherwise, the process of achieving environmental cleanliness in industry can be painfully slow. A comprehension 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). A framework upon which such a principle, oriented to the maintenance of a sustainable development, can be based is further developed here.

In line with this, this study suggests that the waste fractions studied are to be regarded as a kind of company output. This is mathematically considered by adding the sum of the actual quantities of a certain kind of waste belonging to a certain waste fraction set up scenario, to the quantity of normal production output in the denominator in the following expression (3.1) which is to be 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. Expression (3.1) is the model representation of the equality principle expressing its financial implications and that is termed *the model for Efficient Use of Resources for Optimal Production Economy (EUROPE)* (Paper II and Paper VI).

$$\frac{A}{B \ + \ C} \tag{3.1}$$

Where

A = quantity of the waste fraction in question produced
B = quantity of normal product output
C = sum of the quantities of the different waste fractions considered

One must define a suitable production or administrative unit to apply expression (3.1) on. This suitable unit can be everything from e.g. the entire company via divisions or profit centre workshops to an individual machine or any other level of the production system, depending on the circumstances.

The central issue in this work is waste management models. The models are intended to be used by a manager who applies them according to rules coloured by his subjective ideals. Thereby, the goal is to influence the waste flow in companies by the application of certain waste management models. The performance of the production units in question is influenced directly by these models. Therefore, the flow of material through a production unit must be visualised. The manager then applies the waste management model or models of his choice, preferably including the equality principle introduced here. Other models will also be required as the equality principle does not cover all aspects of waste management, such as certain physical handling and judicial aspects. Waste management is, in turn, one among other areas of management and management models that can be applied, this being one component among others in the world of the industrial complex that consists of inter alia producing companies. Virtually the whole manufacturing industry transforms natural resources into products. This implies the production of residual products, or waste, since all the raw material can very seldom be transformed into normal products, although the importance of, for example, recycling must not be forgotten. Therefore, all manufacturing companies, to a certain extent, cause environmental problems. The environment, in turn, is coloured not only by a problematic situation everywhere in all the existing societies all over the globe. These prerequisites for the equality principle context are illustrated graphically in Fig. 3.1.

3.1.2 Cost benefit analysis (Paper I)

3.1.2.1 Method of overhead rates based on normal capacity

The first method to be discussed in terms of possibilities for estimating the "true" internal cost of waste fractionation in terms of the view presented in this work, is that of *overhead rates based on normal capacity*. Mathematically, the problem can be described as follows (Frenckner and Samuelson, 1989):

$$TC = f(x) = Y = FC + VC = FC + k_1 * x, \text{ where } k_1 = (dy/dx) \text{ for } VC \qquad (3.2)$$

$$TR = f(x) = Y = k_2 * x, \text{ where } k_2 = (dy/dx) \text{ for } TR \qquad (3.3)$$

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

Setting $TC = TR$ allows us to obtain the critical point for the quantity of waste required (in kg, tonnes, litres or other units) to fully justify, in purely economic terms, collection of the fraction in question. This is the point where profit increases, i.e. at which the revenue becomes as large as the total cost. This quantity is denoted x_c, or "x critical". From a strictly business point of view, investments in waste treatment equipment would only be justified, on a yearly basis, for fractions that yield a profit. The profit resulting from the amount of a particular waste fraction that was handled in a year ($x_{End of the year}$), assuming that $x_{End of the year} > x_c$, can be calculated as ($TR-TC$). In terms of accounting practices in Sweden (Gerdin, 1995), the estimated costs are allocated as follows:

$$TC/item = [\text{Estimated VC/Calculated quantity of items}] \qquad (3.4)$$
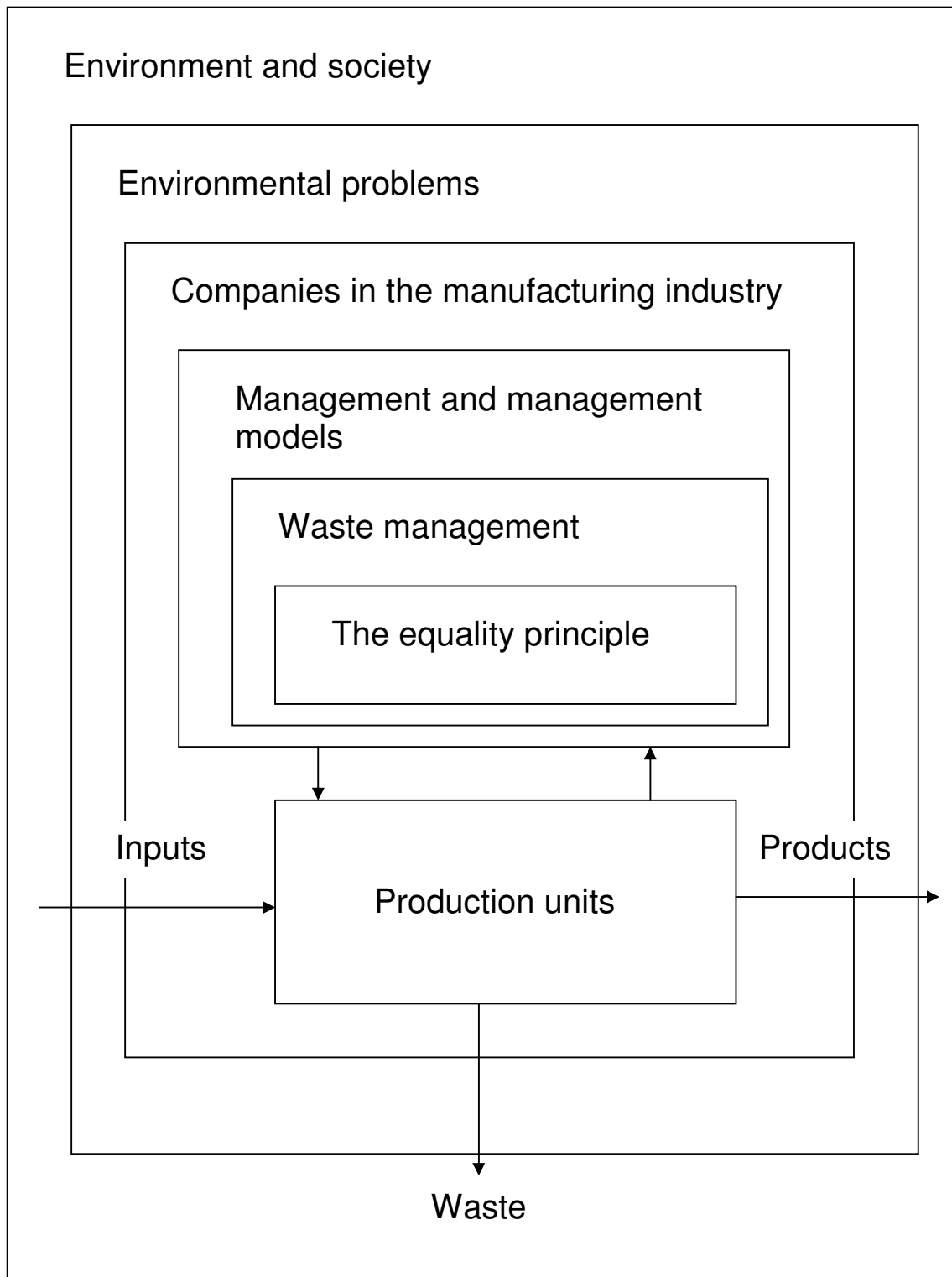$$+ [\text{Estimated FC/Normal quantity of items}]$$

Figure 3.1. Illustration of the waste management equality principle in the production context.

This estimation method is particularly useful when applied to companies that, for the most part, produce only one kind of product. A major advantage of estimating the normal cost is that it eliminates the influence of the company's current level of production, since the FC is always distributed over the quantity that is normally produced, regardless of the current level of production (Johansson and Samuelsson, 1997).

The FC is sometimes difficult to define since it may not be clear which part of the total FC should be allocated to a particular waste fraction. It may be a question of splitting the total FC into parts representing different types of waste. The most natural FC to be allocated to a waste fraction is that for the annual depreciation of equipment and machinery used to separate that fraction. Apart from this, the FC can consist of factors such as interest, depreciation, rent for facilities and the cost of electric or other types of power, for the time period in question. Wages are usually considered as fixed costs and should thus be apportioned between the waste fractions. Examples on bases for the apportioning are the weight or the volume of the waste fraction considered, the quantity of raw materials employed or the time involved in producing the waste fraction of interest under normal conditions. As already indicated by the author, the waste fractions studied are regarded as a kind of company output. This involves adding the sum of the quantities of the different types of waste associated with a given scenario, to the normal output in the denominator of expression (3.1). This study proposes that this expression is used to allocate costs to a particular fraction through multiplication either by the total FC, so as to obtain the FC for the waste fraction in question, or by the second term appearing in (3.4), so as to obtain the FC per item or unit of the waste fraction considered. In this context, it is not unusual for the FC to increase stepwise as the quantity of waste increases, rather than as a straight line (Frenckner and Samuelson, 1989). Such a relationship, if found, should be taken into account.

It is necessary to define a suitable production or administrative unit to which expression (3.1) is to be applied. This may be the entire company, separate divisions or workshops, individual machines, etc.

The VC of a particular waste fraction that is separated depends on the following factors in particular: (i) the amount of manpower or handling time required to collect the waste fraction in question, (ii) the cost of the raw materials and the energy used in the production process in which the waste is produced, and (iii) the cost of ridding the company of the waste material. If the VC directly associated with a given fraction is known, this cost should of course be used. If not, costs can be allocated, just as they were above for the FC, in proportion to the weight or volume of the waste fraction considered, or the amount of raw material used or the time required to produce it. This study proposes that mathematically, allocation is achieved by multiplying expression (3.1) by the first term in expression (3.4). In this case, k_1 is obtained by dividing the estimated total cost of the waste fraction produced during the year in question by the total amount of this waste fraction produced (in kg, tonnes, litres, etc.), in the production or administration unit being studied. It is not unusual, due to economies of scale, for the VC to either increase or decrease progressively (more commonly the latter) as the quantity referred to increases (Frenckner and Samuelson, 1989). If such is found to be the case, this should be taken into account.

The TR for a given waste fraction is a function of factors such as the following: (i) the selling price of the waste, (ii) the value of reusing or recycling it, (iii) the value of the energy extracted if it is incinerated, i.e. a saving in energy that must otherwise be purchased externally, (iv) the saving of fuel, and (v) the avoidance of taxes and/or fees levied on

landfilling the waste. If the TR for a particular fraction is known, this should, of course, be used. If it is not, this study proposes that either k_2 should be calculated in a manner similar to that for k_1 above, using expression (3.1), or the estimated total income arising from the waste fraction in question should be divided by the amount of the waste fraction produced during the time period in question.

The usefulness of the overall approach described above is probably greatest in companies that mainly produce homogeneous bulk goods of different kinds, yielding wastes which, for the most part, stem from the same type of raw material. Such is the case for paper mills, brickyards and dairies, for example. In a company producing many different kinds of goods, the waste from producing goods of one type may deviate markedly from those arising from the production of goods of another type, in terms of either the relative cost of treating the waste, the revenue provided by the waste, or both. In such cases the approach of employing overhead rates that apply under conditions of normal capacity should be used with the utmost caution, or not at all.

3.1.2.2 Average cost estimation method

The second method that can be used when considering a company producing one product only, is to simply divide the total cost for the period in question by the total production during that period, resulting in the cost per ton, or litre etc. However, this *average cost estimation method* has certain shortcomings. The fixed and variable costs are not separated, so it is impossible to include the effects of the level of production activity. If the level of production is sub normal, the estimated cost per unit of waste produced will be higher than if the level of production were normal. Hence, when a long-term decision is required, the costs that apply to a normal level of production should be used (Frenckner and Samuelson, 1989).

In making estimates such as those described above, it may well happen that the quantity of waste sorted (the x-value) falls short of the minimum quantity required (x_c), indicating that the collection and sorting of waste will result in a net financial loss. It may, nevertheless, be necessary to collect the waste and separate the fraction in question, when, for example national environmental regulations require this. Alternative justification for collecting and separating waste, despite the loss incurred, is to regard the financial loss as the value of the goodwill the company may receive for showing responsibility in collecting and sorting its waste. The total loss, or the goodwill involved, can be calculated mathematically as the absolute value of (TR-TC) for the amount of the waste fraction handled during the year of interest ($x_{End of the year}$), assuming that $x_{End of the year} < x_c$.

This study proposes that when applying the average cost estimation method, the cost of a given waste fraction is determined by multiplying expression (3.1) by the actual or budgeted average cost for the period in question. However, this will result simply in a cost of the waste per unit of the current total amount of waste in question.

3.1.2.3 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*, used here in a somewhat modified form. 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. This is the

case in ironworks, spinning mills and weaving mills, for example. Costs are then allocated on the basis of equivalent rates calculated for normal production conditions, normal cost levels and a normal mix of products. The equivalent rates indicate relationships between the costs of the different products. This study proposes that calculation of the equivalent rate (ER) for a particular product during a given period is carried out in accordance with equation (3.5).

$$ER = \frac{D}{E} \qquad (3.5)$$

Where

        D = normal cost per unit for a given product
        E = normal cost per unit for the product with the lowest cost per unit

Assuming a normal level of production, which allows this average cost estimation method to be employed, one can estimate the cost due to a given waste fraction during a particular (past or future) period using a modified version of expression (3.1):

$$\frac{A}{F \;+\; G} \qquad (3.6)$$

Where

        A = quantity of the waste fraction in question produced
        F = Σ (quantity of the associated product produced *
            this product's waste equivalent rate)
        G = Σ (the quantities of the various waste fractions produced in
            the fraction scenario considered)

The cost of a given waste fraction is then determined by multiplying expression (3.6) by the actual or the budgeted cost of some suitable unit for the period in question (past or future).

3.1.2.4 Absorption costing method

The fourth method of estimation to be considered in connection with the separation of waste fractions is the *absorption costing method*, also used here in a somewhat modified fashion. This method involves a step-by-step analysis of the contribution of the separate costs to the final cost units, taking into account the following:

- the distribution of direct costs in the final cost units
- the distribution of indirect (overhead) costs in the sub-organizations involved (such as departments)
- the distribution of the costs of the sub-organizations involved in the final cost units.

The direct costs usually include the following:

- direct material costs (DM)
- direct labour costs (DL)
- special direct manufacturing costs, such as patent costs
- special selling costs, such as commissions

Indirect costs are usually divided into the following four major categories:

- material overhead costs (MO), such as those for storage, and the wages of the store and purchasing staff
- production overhead costs (PO), such as those for the salaries of the planning and design department staff and for the depreciation of machines and buildings
- administrative overhead costs (AO), such as those for central management and for the financial and personnel departments
- sales overhead costs (SO), such as the salaries of sales management personnel and of salesmen (excluding commissions), and costs for PR.

AO and SO are usually combined to form the category "sales, general service and administrative expenses" (S, G & A expenses).

MO, PO and S, G & A expenses are usually divided as follows:

$$(MO_{Total}/DM_{Total}) * 100 \ (\%) = \text{Rate of absorbed indirect material costs} \qquad (3.7)$$

$$(PO_{Total}/DL_{Total}) * 100 \ (\%) = \text{Rate of absorbed production overhead costs} \qquad (3.8)$$

$$(S, G \& A_{Total}/\text{Total production cost}) * 100 \ (\%) = \text{Rate of absorbed general} \qquad (3.9)$$
administration and marketing and sales overhead costs i.e. the S, G & A expenses rates.

Estimates for a given product are then made as shown in Table 3.2.

Table 3.2. Basic set-up for the absorption costing method.

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

This study proposes that the possibility of using this method in connection with the assessment of the profitability of separating waste fractions lies in multiplying expression (3.1) by "Total cost" in Table 3.2.

3.1.2.5 Activity Based Costing (ABC) method

The *Activity-Based Costing (ABC) method* is the fifth method to be considered in connection with waste fraction separation, again used in a modified form. This method is based on the

fact that, whereas at one time most manufacturing companies used the number of working hours involved as the main basis for allocating costs to products, in modern companies that are highly automated, labour costs may represent only 5-10% of the total manufacturing cost and often bear no direct causal relationship to the majority of overhead costs. Thus, the use of working hours, possibly together with machine-hours, as the only basis for estimating costs seldom meets the cause-effect criterion, which is the aim in cost allocation exercises. If many of the costs arise from factors that are non-volume-based, the ABC method is clearly applicable. This is a method in which the costs of each activity in which an organization is engaged are determined and then linked to the products, services or other objectives with which costs are associated. The aim is to trace costs to products or services instead of arbitrarily allocating them (Johnson and Kaplan, 1987). Since costs are often linked to the number of transactions involved in the activity in question, ABC is also called *transaction-based costing*. Examples of transactions that can be regarded as cost-driving factors here are production orders, material requisitions, adjusting machines and commissioning them, product inspection, material shipments received and orders shipped.

The possibility of using the principle of proportionality, as expressed in expression (3.1), in an ABC context and of applying it to a highly complex product is illustrated by an example taken from Horngren et al. (2002), in which a company manufacturing technical instruments has an activity-based system involving four basic activities concerned with the treatment of waste (Table 3.3).

Table 3.3. Example taken from Horngren et al. (2002) of activities concerned with the treatment of waste in a company manufacturing technical instruments.

Activity	Cost driver	Rate (monetary units (MU))
Handling of materials	Number of components	A MU per component
Engineering	Hours of engineering services	B MU per hour
Setting up production	Number of set-ups	C MU per set-up
Assembly (automated)	Number of components	D MU per component

Table 3.4 gives the cost-driving activities, measured in terms of the number of transactions required for the manufacture of a particular technical instrument.

Table 3.4. Cost-driving activities for the manufacture of a particular technical instrument.

Activity	Number of transactions required
Number of components	E
Hours of engineering services	F
Number of machine settings	G (1/number of units per machine setting)

Table 3.5 indicates the final calculations needed to obtain the total cost of the separation of a given waste fraction produced in the manufacture of an individual component of a particular instrument. It is assumed that the waste in question stems from a pipe which is one of E components in the instrument, costing H monetary units (MU) for the total material used and I MU for the direct labour involved. The mass (weight or volume) of the total waste from the pipe and other sources is known. The cost of the waste from the pipe is assumed to increase with the mass of the waste from the pipe. This study proposes that the proportionality factor K given in expression (3.10), which is similar to expression (3.1), applies here.

$$K = \frac{\text{Mass of the waste from production of a single pipe}}{\text{Mass of the instrument} \quad + \quad \text{Total mass of waste from producing the instrument}} \qquad (3.10)$$

Table 3.5. Principles for allocating costs to waste using the ABC method.

		Calculation
	Direct material costs	H MU
+	Direct labor costs	I MU
	Activities	
+	Handling of materials	A MU * E
+	Engineering	B MU * F
+	Setting up production	C MU * G
+	Assembly	D MU * E
=	Total cost	Total cost of producing a single instrument
	Cost to be allocated to pipe waste	(Total cost for a single instrument) * K

Although applying the allocation principles contained in expression (3.1) to the five methods described above redistributes the cost of regular products to waste - which does not necessarily result in an increase in the *total* cost for the company involved - 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. What can be termed "environmental shadow prices" should therefore be used in combination with the cost allocation principle in defining environmental standards. Even *without* the application of such environmental impact weighting, the cost allocation principle is useful internally as a means of redistributing costs related to waste between the different departments of a company, resulting in a form of competition between the production units, enhancing environmental improvement and company profit.

3.1.2.6 Remainder method

The sixth method, the *remainder method* represents a different approach to cost estimation, yielding an average cost. This method can be applied to a company that produces one or more by-products along with its main product or products, and that does so in such a way that the manufacturing of these two categories of products cannot be separated. An example of this is a mill that produces both bran and flour. If flour is the main product, then taking the company's total cost and subtracting the revenue obtained from the sale of the by-product, say bran, can determine the cost associated with producing the flour. The result is then divided by the quantity of the main product produced, so as to obtain the main product's manufacturing cost per unit. Such an approach is useless in the context of allocating costs to different waste fractions. However, since it is designed to give the manufacturing cost of the main product only, not taking into account the costs associated with by-products. Only the net revenue resulting from the by-product is considered explicitly. The remainder method is, therefore, not compatible with the principle proposed in this paper of equating by-products (solid waste)

with regular main products in terms of costs and revenues. Accordingly, it is not discussed further.

3.1.3 Contribution margin analysis (Paper II)

Contribution margin analysis (CMA) is a method of fundamental importance in the business context. It 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 (Frenckner and Samuelson, 1989). 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 (Horngren et al., 2002). The contribution margin tends internationally, therefore, to be calculated as follows (Johansson and Samuelsson, 1997).

1. Unit sales price of the product is estimated
2. Variable cost of a single unit of the product is estimated
3. Contribution margin for a single unit of the product is estimated as the difference between the sales price and the variable cost for that unit
4. Final assessment of profitability is based on the relation of the estimated contribution margin to either the resources required or the minimum contribution margin acceptable to the company.

In contrast to cost-benefit analysis, CMA is used mainly for short-term decisions concerning the resources available at the time. Accordingly, it is assumed that, for the use of CMA to be reasonable, the following conditions should remain relatively constant within the period of time involved (Olsson and Skärvad, 2000):

- product mix or product assortment;
- demand for the product, or consumer preferences for it;
- manufacturing capacity, where the maximum amount that can be produced remains basically the same.

It is usually a question, therefore, of making use of existing plants and the existing workforce in as profitable a way as possible. The crucial issue is whether the income from the waste fraction in question fully covers the fixed cost connected with it. If it is assumed that sufficient manpower is available, 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 3.6.

Table 3.6. Scheme for estimation of the contribution margin, shown here for the fraction of waste sold (cf. Horngren et al., 2002).

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 =
= 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.

Assessment of the specific income and the specific fixed and variable costs, which is an important step, can be carried out with the use of traditional economic theory. The problem can be described as follows (Frenckner and Samuelson, 1989) (cf. 3.1.2.1):

$$TC = f(x) = FC + VC = FC + k_1 * x, \text{ where } k_1 = (dy/dx) \text{ for VC} \qquad (3.2)$$

$$TR = f(x) = k_2 * x, \text{ where } k_2 = (dy/dx) \text{ for TR} \qquad (3.3)$$

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

Setting TC = TR allows one to obtain the critical point for the quantity of waste (in litres, kg, tonnes etc.) required in purely economic terms, to justify collection of the fraction in question. This is the point at which, as profit increases, the revenue becomes as large as the total cost.

Examples of FC that may be involved are depreciation, interest, rent, electric power and wages, each or some of which may have to be divided between different waste fractions. This can be done in terms of the volume or weight of the waste fraction, the time normally required to produce it, or the quantity or cost of raw materials used.

Treating each waste fraction as a product involves adding the quantities of the various waste fractions to the output, as is done in the denominator of expression (3.1). This is used for apportioning costs to separate fractions for a particular production or administrative unit - which may be the entire company, separate divisions or workshops, individual machines, etc. This study proposes that this assignment involves multiplying expression (3.1) by the total FC to obtain the FC for the waste fraction in question.

The VC of a particular waste fraction depends on factors such as the manpower or handling time required for collecting it, and the cost of the raw materials or energy consumed in the process in which it is produced. This study proposes that if the VC directly attributable to a given fraction cannot be determined, costs can be allocated, just as for the FC above, in proportion to the weight or volume of the fraction, or to the amount of raw material or time consumed in producing it, by multiplying the respective VC by expression (3.1). The term k_1 in expression (3.2) is obtained by dividing the estimated total cost of the waste fraction by the amount produced, for the time period and the production unit in question or whatever involved. It is not unusual, due to economies of scale, for the VC to either increase or decrease progressively (more commonly the latter) as the quantity involved increases (Frenckner and Samuelson, 1989). If such is found to be the case, this should be taken into account.

This study proposes that if TR for a particular fraction cannot be determined, the recommended procedure is either to implement expression (3.1), in a manner similar to that for FC and VC above, or to calculate k_2 in expression (3.3) by estimating the income stemming from the waste fraction in question and divide this by the number of units, in tonnes, litres etc., of the waste fraction produced during the corresponding period.

After FC, VC and TR have been obtained for a given waste fraction, the operating income (or contribution margin), is estimated, for example, as income per unit of waste produced. This study proposes that this operating income is then incorporated into current wastes, after all relevant internal estimates have been made of short-term character, such as those for product costs. In this way, the existence of the waste fraction in question affects the estimate of the desired operating income.

In the case of n waste fractions, the total contribution margin can be calculated as follows:

$$CM_{tot} = \Sigma \ (CM_j \ x_j) \tag{3.11}$$

Where

CM_{tot} = Total contribution margin of the n waste fractions
CM_j = Contribution margin per unit of waste fraction j calculated using expression (3.1) involving shadow prices
x_j = The amount of tonnes, litres etc. of waste fraction j
$x_j \geq 0, j = 1, 2, 3, \ldots, n$

The total contribution margin or operating income according to expression (3.11), when calculated for a certain waste management scenario, can be used as input for short-term product cost and investment assessment in order to deal with a more complex waste management situation involving many waste fractions.

Although the application of the EUROPE equation as expressed in (3.1) to the CMA method discussed above redistributes some of the cost of normal products to wastes, without this necessarily resulting in any increase in *total* cost for the company, it does not directly link the avoidance of wastes with the incentive to reduce total costs, as specified in the consolidated profit and loss account used for business purposes. However, this study proposes that weighting can be used to adjust the costs associated with a particular type of waste to its environmental impact, based on scientific evidence and/or in terms of overall societal aims. What can be termed "environmental shadow prices" should thus be used in combination with the cost allocation principle in defining environmental standards. Even *without* the use of such environmental impact weighting, the cost allocation principle is useful internally as a means of redistributing costs associated with waste between different departments of a company. This results in a form of competition between different production units, enhancing environmental improvement and profit. This gives companies an incentive to reduce wastes in order to improve their contribution margin estimates. This improvement incentive has impact on short-term product cost estimates, for example, and thus on budgets and on forecasts used as a basis for loan applications, for example, and on information to company stakeholders.

3.1.4 Polluter-Pays Principle (Paper III)

A commonly suggested way to cope with the pollution aspect of the waste problem, is to apply the *Polluter-Pays Principle* (PPP), i.e. 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).

In 1972, the member countries of OECD agreed to base their environmental policies on the PPP. The intention was to encourage industries to internalise environmental costs and reflect them in the prices of products (WCED, 1987). In the economic theory, internalisation means that a cost which otherwise would be borne by an economic agent, other than the polluter, is charged to the polluter who, as a result, "internalises" such costs with all the other costs he already bears (OECD, 1992).

However, in practice PPP is only partly applied within the industry of today when making estimations concerning e.g. optional methods for waste management; an industry usually takes only the business economic cost for handling a certain waste fraction into account. The firm estimates e.g. the fee for deposit of the waste at a landfill and the related transportation cost or the cost of some other treatment method compares this with the expected revenue from e.g. conversion or incineration, and nothing else is considered. Of course this approach doesn't reflect all occurring environmentally related costs as a result of the produced waste.

In order to ensure sustainability for business and industry, a shift of paradigm is necessary. This study claims that industry's response to pollution and resource degradation should not be limited to compliance with regulations. It should also involve acceptance of a broad social responsibility and an awareness of environmental considerations at all levels. This implies that the costs to industry stemming from the fact that waste and pollutions indeed occur, must to a much larger extent include also the costs of the negative impact on the environment and society at large that results from all the output from the industry in question.

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 occurring necessary costs for making the production process environmentally friendly in a company - which is called the environmental adjustment costs - to the residual waste products involved. This additional allocation can be in relation to the weight, volume or value of the waste or time required to handle it.

This study proposes that expression (3.1), 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. One needs to decide upon a suitable production or administrative unit to which expression (3.1) is to be applied. This can be the entire company, separate divisions or workshops, individual machines or any other level of the production system. Environmentally related shadow price costs are allocated to the waste that is produced and are incorporated into the internal cost calculations of the company so to induce corporate waste reducing incentives leading to cleaner production processes.

3.2 Construction waste management models; Block Opus 1

(Paper VI)

This sub-chapter presents facts and results for the construction site case study object in question and is based on the appended Paper VI. The source is mainly interviews with site manager Civil Engineer André Ilvemark and the statistical and financial material that he provided.

3.2.1. Project description

The construction project consisted of three residential three-storied houses with two flats per storey, thus in total eighteen flats. Opus 1 is intended for elderly people and was built by the construction company JM Bygg AB between August 2001 and September 2002, in total a construction period of thirteen months. The total cost of production was approx. MSEK 32 excluding purchase of land but including MSEK 13 for materials and MSEK 3 for expenses including costs for garage and storehouse. See the appended Paper VI for breakdown of costs. (At the time of writing (February 2003) USD 1 equals approx. SEK 8.50.)

The book keeping and accounting system worked in the way that bills were scanned by the public postal office service and sent as attachments via e-mail to the site manager. He used the program E-flow to allocate the right account number to the bills by a computer on the site and finally archived them. The economy system used was called R3. It was construction material directed, e.g. for disks and beams etc. The later versions of R3 that are to be used for Opus 2 and Opus 3 will be able to handle construction object parts also.

The program BidCon, version 5.1, by Consultec was used for tendering, estimations during the project and for follow-ups. BidCon is based on drawings to use to select a suitable picture of certain construction parts in the database. The construction parts are then changed to apply to the object in question. The site manager reconciled by using Excel sheets that he designed himself to show how much that was paid according to the BidCon estimations based on construction parts that were built in. The program R3 then gave the final financial result for the time being as a net estimation i.e. the contract sum minus the cost for materials built in.

3.2.2 Construction description

Opus 1 has a total area of 2700 m^2. There is a total garage area of approx. 500 m^2. The ceiling height is 3 m (see appended Paper VI for specification of the calculations).

The foundation consists of a concrete frame with pedestals because of ground water impact. The framework is 150 mm concrete and 195 mm cross bars. The insulation is mineral wool. The plasterboard is 9 mm thick. The batten has the dimensions 34 mm X 70 mm. The panel consists of two types of larch. The trabeation on the gables was constructed in situ. The roof is made of prefab rafters covered with bituminized paper on tongues.

3.2.3 Waste handling system

In practice, the waste handling system of Opus 1 was designed in the following way: The construction workers put the waste in vats on wheels. The vats had signboards on them showing what waste was to be placed into them and the vats followed the men wherever they went to do their jobs in the house. The workers emptied the vats in containers that were placed in the lawn. The containers were marked in the same way as the vats to show what waste was to be placed in them, based on an assortment system specially designed for Opus 1.

The transportation company Akka Frakt AB transported the wastes to the waste emptying station of the waste management company SYSAV using containers at a total cost of about SEK 48,534 including rent for containers and fees for tipping. About 15% of that cost consisted of miscellaneous items such as costs for cranes and transport of construction equipment from storehouses of JM AB to the site. SYSAV tipped at the waste reception plant Spillepengen or in Trelleborg for a total waste fee of SEK 53,791. In total, 55 transportation trips for emptying the waste from Opus 1 took place. Thereby, 12 m^3 containers were used corresponding to 660 m^3 waste transported from Opus 1 (12 m^3 waste per container * 55 containers = 660 m^3). The transportation company ÅGAB took charge of the cast concrete waste.

To make this system work, the site manager gathered representatives of the sub contractors and the waste handling company SYSAV plus the building trade workers. In a meeting before the start of the construction works the system was scrutinised in advance at the very site and its importance was impressed on the foremen and managers in question. Experience showed that it was important to have very big text on signboards on vats and containers. Also pictures of concrete examples of fractions of current waste adapted to the current situation for the project in question should be put on the signboards.

In practice, the waste handling system worked out very well indeed. The separation at the source was successful as much as wastes were not mixed in the different containers. Also, the public did not make use of the possibility to put their private waste in the containers on the site. To a large extent this fact is due to the fact that the site area was closed and guarded.

3.2.4 Waste statistics

The waste that occurred at Opus 1 was broken down into different fractions approx. according to the presentation in the appended Paper VI. Specifically, it should be mentioned that gypsum wallboard inner walls stand for approx. 10% of costs as well as weights of construction sub-components for wastes at Opus 1. This figure (10%) is consistent with findings from studies of the break down of Swedish construction (building) waste performed by Sigfrid (1994 a, b). In these waste inventory studies, the gypsum fraction is shown to represent approx. 16% of the total weight of the waste from a representative building object (Block Midhem in Malmö).

4 Construction waste management models – SHOULD BE-mode

This chapter presents, in comparison with the IS-mode, a possibly more efficient construction waste management system, if the models that are introduced here are applied in practice. The formulation of the SHOULD BE-mode takes its stand in the conducted investigation of the IS-mode and the appended papers (Paper I, II, III and VI (the Block Opus 1 site case study)) and is based on adequate waste management theory and experiences. The strategy behind the formulation of the SHOULD BE-mode has its origin in the target formulation of the investigation project. The target of the project defines the direction of the scientific effort as expressed in the formulation in chapter 1.7 of the project objectives.

4.1 Waste management models usage analysis

This sub chapter presents the analysis performed for the appended papers and the block Opus 1 case study as regards the applicability of the equality principle introduced (Stenis, 2002) in a construction waste management perspective. The theoretical framework that was introduced previously (Stenis, 2002) is, where possible, adapted to a construction management environment based on the findings from the block Opus 1 site case study to exemplify the proposed method modifications. The suggestions made and the corresponding analysis is the scientific basis for the "Statement of the SHOULD BE-mode" that follows.

4.1.1 Cost benefit analysis

4.1.1.1 General industrial waste management applicability

The appended Paper I shows how the principle of the equating of industrial waste with regular products in a business sense can be applied to traditional cost-revenue methods as a financial basis for environmentally friendly waste management. Results of the case study show that, in terms of the equality principle (Stenis, 2002), the "true" internal shadow price costs for the presence of (solid) waste are substantial, the exact costs obtained differing according to the method employed.

4.1.1.2 Construction waste management applicability

Specifications of variable and fixed costs are usually never considered to be of importance when performing estimations and follow-ups of construction objects. If so, these costs must be specially estimated and someone must hence categorise different classes of costs. Usually there is no need to do this. Thus, there are no estimations available of variable and fixed costs for Opus 1. Therefore, the method of *overhead rates based on normal capacity* - that is based on the existence of figures for variable and fixed costs, mainly for the use on companies producing homogenous bulk goods - cannot be applied in a construction waste management perspective, and it is therefore disregarded.

The *average cost estimation method* is useful when the industry studied is producing one product only. However, it is nevertheless possible to look at a certain waste fraction and check what happens if the theoretical framework developed in 3.1.2 is applied on e.g. gypsum wallboard inner walls. According to Paper VI, gypsum wallboard inner walls account for 10 % of the total cost for wastes. This gives a shadow price cost per tonne of the waste fraction of SEK 800 to be allocated to each tonne of the waste fraction. (See the appended Paper VI for specification of the calculations.) This can be compared with the example in 1.2 giving a cost per tonne for spillage of gypsum wallboard, excluding the cost of labour, of approx. SEK 3000. 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 based on the same raw material and with similar manufacturing methods, examples being e.g. ironworks and spinning mills etc. 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 and it is therefore disregarded.

According to site manager Civil Engineer André Ilvemark, JM AB, and several other well informed persons from the Swedish construction industry, the net cash flow principle is used throughout Swedish construction industry and also internationally when performing follow-ups of construction objects.

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 the 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 and it is therefore disregarded.

The *Activity Based Costing (ABC) method* is used in construction industry to the extent that usually estimations are made for specific construction components, taking into account the amount of time needed to produce them. Also the follow-up is usually adapted to the existence of construction components i.e. in a certain way to activities. However, if the equality principle concept introduced (Stenis, 2002) 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. It is therefore disregarded.

The *remainder method* is applicable mainly on industrial companies producing by-products which cannot be separated from the main products, the emphasis being on giving the manufacturing cost for the main products only. This is not a useful way as regards construction waste since the major principle for such an estimation method must concentrate on the waste and not the building itself in order to be useful. Therefore, the remainder

method cannot be applied in a construction waste management perspective and it is therefore disregarded.

4.1.2 Contribution margin analysis

4.1.2.1 General industrial waste management applicability

The appended Paper II shows how the principle of equating (in a business sense) industrial waste with regular products can be applied to traditional cost-revenue methods so as to provide a financial basis for environmentally friendly waste management.

4.1.2.2 Construction waste management applicability

If certain machines in a fixed industrial production plant suddenly become available and have free extra capacity, the plant can produce many extra products because of the "gap" in the flow of products. A construction site does not produce separate products that are sold piece by piece, such as e.g. cars from a factory, but is one big product that is bought in one big piece. Of course, there exist plans for payment based on what and how much that is produced during a certain period. But still, usually no single separate products are sold as is the case for the common industrial factory. Also, there are condominiums that can be sold one by one, but then usually the whole house is sold by the construction company to the tenants' owners' society in question once and for all. So, in a construction object, there are no included single products produced that can be profitable and e.g. really give a positive contribution margin in the traditional industrial way.

Furthermore, as stated under 4.1.1.2, specifications of variable and fixed costs are usually never considered to be of importance when performing estimations and follow-ups of construction objects. If so, these costs must usually be specially estimated and someone must categorise different classes of costs. Usually there is no need to do this. Thus, there are no estimations available of variable and fixed costs for Opus 1. Also, it would theoretically be possible to perform a CMA on a specific waste fraction. However, this would require fixation of variable and fixed costs for that certain fraction. That would be very difficult to do in practice, this requiring tedious, highly impractical allocation of the total costs to various fractions. Therefore, the contribution margin analysis method that is based on the existence of figures for variable and fixed costs is not suitable for application in a construction waste management perspective and it is therefore disregarded.

4.1.3 Polluter-Pays Principle

4.1.3.1 General industrial waste management applicability

The most basic proposition the appended Paper III deals with is that of considering waste to have the same status as regular products in a business economic sense – what was termed in an earlier work (Stenis, 2002) the equality principle - and of expecting waste, therefore, to carry its full costs in the production process. Applying this principle in a straightforward way to estimates of current net profit on investment, using both Polluter-Pays Principle (PPP), which the paper focuses upon, and a strict full-cost proportionality approach in which profit and loss is assigned to the different waste fractions in proportion to their respective weights

(or some analogous quantity), shows – in two case studies - the waste fractions considered to have a negative impact on the bottom line. The loss in question is found, through use of appropriate shadow prices, to affect the profit and loss account in a manner providing the company an incentive for reducing waste.

In terms of the approach described, waste unit costs should reflect economically the inability of the investments in question to reduce the occurrence of waste. According to principles for estimating investment and product costs, the additional costs allocated to the various waste fractions should affect the financial result of the company negatively. The reasoning here is that, in strict economic terms, an investment that is profitable and environmentally friendly, such as in a production process, results in the company's is being rewarded economically for its investment, whereas an investment that is not profitable gives the opposite result. The principle described gives the company in question, therefore, an incentive to make profitable, environmentally related investments and also to reduce the occurrence of unprofitable waste.

It is shown that PPP can be incorporated into the financial accounts of a manufacturing company. There appear to be no specific obstacles to applying the equality principle to either a bulk industry or the manufacture of technically complicated products. The overall approach described can be assumed, therefore, to be applicable generally to industrial firms producing waste.

4.1.3.2 Construction waste management applicability

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 SEK 0,15 to be allocated to each tonne of the waste fraction. See Paper VI for specification of the calculations. This can be compared with the example in 1.2 giving a cost per tonne for spillage of gypsum wallboard, excluding the cost of labour, of approx. SEK 3000 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.

4.1.4 Collocating analysis

4.1.4.1 General industrial waste management applicability

The findings point at fruitful possibilities to modify commonly used cost-revenue estimation methods including the PPP in an industrial waste management context by the use of the equality principle introduced. Therefore, performance of waste management can be said to be possible by the use of (altered) economic models. Therefore, the generality of the results is good. This implies that there are good chances to change relevant general attitudes to the waste phenomenon, which is regarded as necessary to achieve a clean enough environment. See the appended papers for information on the technical aspects of the companies studied.

Generally, the financial impact of the application of the theory developed in this work is greater in relative terms the bigger the total cost is for the system in question. An example among others is a plant for so called reverse osmosis that is described by the author in a paper (Thörneby et al, 2003) not appended here.

4.1.4.2 Construction waste management applicability

As shown in 4.1.1.2, 4.1.2.2 and 4.1.3.2, the possibilities for applying the equality principle introduced previously (Stenis, 2002) are biggest 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, the application of the Polluter-Pays Principle in a construction waste management perspective normally is expected to give financial corporate incentives that are too small to justify its use.

The average cost estimation method can be expected to give reasonable construction waste management consequences when applied to the demolition of a construction object according to the equality principle. The same economic incentive for minimising the material that is not utilised will occur regardless of whether the demolished house in question is rebuilt on the spot, whether the house is disassembled at the waste management company in question or whether the disassembly takes place on the construction site.

Also, 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, a recommendation of the preferred alternative would logically be that, in the first place, the average cost estimation method should be used to allocate costs to wastes when fulfilling the ambition to apply the equality principle on construction waste management (Paper VI).

However, practical obstacles to the implementation in practice of new models for waste management and other new phenomena are prevailing within construction industry. Above all, there exists a strong threshold resistance against innovations among the dominating majority of conservative men within the conservative construction industry (Swedish Government Official Report (SOU) 2002:115). This fact may imply that one can expect a certain amount of unwillingness to immediately adopt new principles for how to in practice allocate mainly costs to construction waste according to e.g. the theory presented here. Thus, an adequate pedagogic effort in the future is a necessity in order to achieve a full understanding in practice for the advantages of the new waste management concept presented in this work. However, these aspects are not further elaborated because of the delimitations of the work (see 1.8).

4.1.5 Sensitivity analysis

4.1.5.1 General industrial waste management applicability

Here is referred to the papers that are appended. The case studies in the papers are being regarded as sufficient in themselves to provide the reader with an acceptable comprehension of the level of sensitivity in the results obtained in the papers.

4.1.5.2 Construction waste management applicability

The sensitivity analysis is performed based on the suppositions that a) the waste is taken care of free of charge as regards tipping, b) the waste is taken care of at the current tipping fee and c) the waste is taken care of at a the double tipping fee. The other component in the total waste handling cost, the transportation, is supposed to be constant because of it is considered to be unavoidable. The cost of labour for handling the waste is excluded in the analysis because it is very difficult to extract in exact amounts from the total cost of the Opus 1 project. The results of the sensitivity analysis are summarised in Fig. 4.1. The calculations can be found in Appendix 7.

The average cost estimation method

Free tipping;
267; 13%

Doubled fee;
1067; 50%

Current fee; 800;
37%

The Polluter-Pays Principle

Doubled fee;
0.01; 5%

Free tipping;
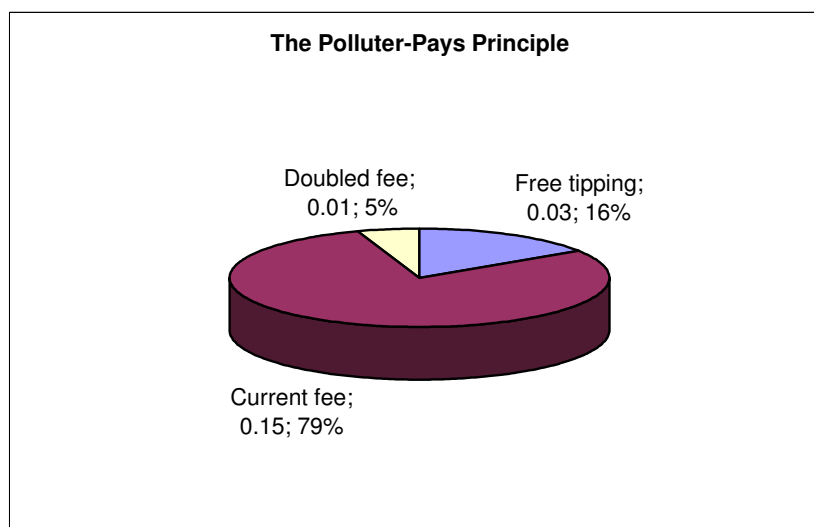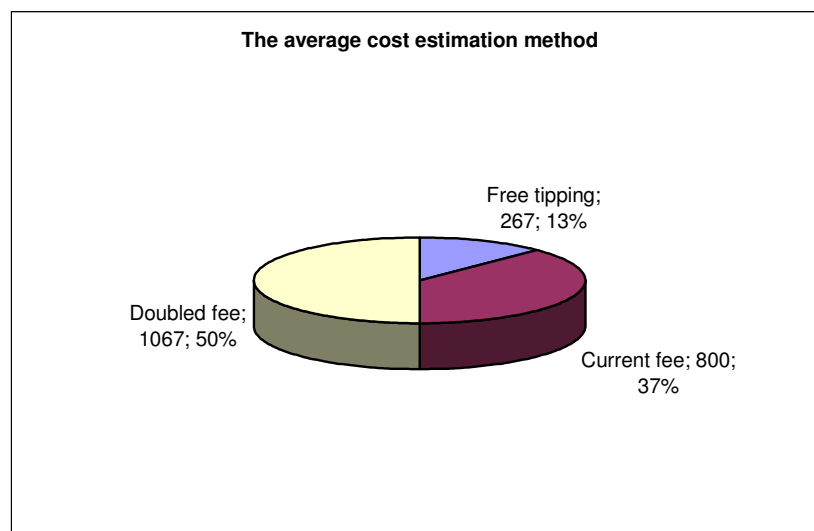0.03; 16%

Current fee;
0.15; 79%

Figure 4.1. Cost of the waste fraction to be allocated per tonne of gypsum wallboard produced at the construction object block Opus 1 for different SYSAV tipping fees, using the average cost estimation method and the Polluter-Pays Principle (SEK (in absolute value)).
In total, the sensitivity analysis indicates that the average cost estimation method shows the most stable outcomes as a consequence of the tipping fee being alterated systematically. E.g. a doubling of the current tipping fee gives a rather modest 33% increase according to

$$((SEK\ 1067 - SEK\ 800)\ /\ SEK\ 800)\ \% = 33\%$$

in the cost (SEK 1067 / tonne) to allocate to the waste fraction studied. This can be compared with the example in 1.2 giving a cost per tonne for spillage of gypsum wallboard, excluding the cost of labour, of approx. SEK 3000 excluding the cost of labour. 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 also in the light of drastically increased costs for e.g. waste fees.

The situation is of a similar nature as regards the sensitivity if the analysis is performed with environmental taxes and fees as the objects of study. This can be regarded as a kind of tipping fee, associated to the amounts of wastes produced, e.g. tonnes, and disposed of. The impact of different scales of tipping fees on the theory developed here has already been analysed. Therefore, the sensitivity analysis can be said to encompass the impact of possibly future proposed environmental taxes and fees as well.

On the other hand, the Polluter-Pays Principle approach application of the equality principle (Stenis, 2002) shows extremely large variations in the cost to allocate to the waste fraction in question when the tipping fee is altered. Thus, the findings based on applying the theoretical framework studied on a most representative construction object from the "real world" imply that the average cost estimation method is mainly suitable to use for allocation of costs according to the equality principle introduced (Stenis, 2002).

The construction object Opus 1 shows a traditional set up of included construction materials. This is reflected in the breakdown of main waste fractions according to Table 3.10. Other typical construction materials that are not represented in Opus 1 are e.g. steelworks, aluminium and bricks. This fact may theoretically affect the present investigation of the applicability of the equality principle concept on construction waste. However, the theory of allocation of mainly costs developed here is neutral as regards the materials that are considered. Therefore, the results of the present study, using Opus 1 as a practical example, can be expected to be generally applicable as regards construction waste.

As regards demolition aspects on sensitivity for construction waste management applications, the equality principle can be expected to produce results of basically the same relative magnitude as for original production. The average cost estimation method will in this context, in principle, give the same incentive to produce less waste when applied on a demolition object as well (Paper VI).

4.1.6 Validity and reliability

4.1.6.1 General industrial waste management applicability

As mentioned earlier, the terminology validity and reliability is applicable mainly on the modifications of the economic models performed. Generally, according to Thurén (1993), validity should be understood as whether the research has been aimed at investigating what was intended to investigate. The reliability is said to measure to what extent the investigation is reliable and trustworthy.

The validity is regarded to be good in this research project as regards the general industrial applicability. Economic models that are commonly accepted since long ago and thus suitable for the purpose of the investigation are applied through out. Therefore, the main objective of the study to a certain extent can be said to be fulfilled.

The reliability is considered to be acceptable. Relevant textbooks with a high degree of trustworthiness are used through out as a basis for the elaboration of the method theory in question. Therefore, the results to a certain extent can be said to be trustworthy as well.

The basis of the choice of reference literature is that the literature is commonly known in order to get a broad view of economic management models. Therefore, certain examples of business economic theory that can be said to be relevant possibly can be omitted. This risk is however regarded to be less important to consider since the modification of the economic models in question is performed with the purpose of providing a general model framework for waste management applications. Therefore, no highly specialised or rare economic theories are likely to be necessary to use as basis for the study. The commonly known theories should be quite sufficient. Also for this reason, the reliability is fully acceptable.

4.1.6.2 Construction waste management applicability

The validity is regarded to be good in this research project as regards the construction waste management applicability. Economic models that are commonly accepted since long ago and thus suitable for the purpose of the investigation are applied throughout. This is so since one main objective of the study was to investigate the applicability of the economic models studied previously (Stenis, 2002) in a construction waste management context. Therefore, the main objective of the study to a certain extent can be said to be fulfilled. The performance of the construction site case study Opus 1 strengthens the validity of the work because it gives a determining contribution to the focus on the very subject of the work and hence improves the focus on the intended main object of investigation.

The reliability is considered to be acceptable. Relevant textbooks with a high degree of trustworthiness are used throughout as a basis for the elaboration of the method theory in question. Therefore, the results to a certain extent can be said to be trustworthy as well. The performance of the construction site case study Opus 1 strengthens the reliability of the results in the work because it gives a determining contribution to the trustworthiness of the results obtained. The results are hence supported by relevant facts taken directly from the daily reality from a most representative construction site suitable for the objectives of the overall work (Paper VI).

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4.2 Statement of the SHOULD BE-mode

In order to improve the environment and to improve the economy of industry and the construction companies in the long run by possibly making the production process more efficient as regards the use of resources, according to the view presented here, costs can be allocated to industrial and construction waste based on the allocation expression (3.1) that is termed *the model for Efficient Use of Resources for Optimal Production Economy (EUROPE)* (Paper II and VI).

Thereby, the basis for the allocation does not have to be mass (kilograms or tonnes etc.) but can be e.g. volume or costs for the output in question as well.

As regards *general industrial conditions*, commonly used cost-benefit methods (Paper I), the contribution margin method (Paper II) and the Polluter-Pays Principle approach (Paper III) can, according to the view presented here, be applied in a modified way through the use of (3.1) the basis of which is the equality principle introduced (Stenis, 2002).

As regards *construction management conditions*, the average cost estimation method can, according to the view presented here (Paper VI), be applied in a modified way through the use of (3.1) the basis of which is the equality principle introduced (Stenis, 2002).

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5 Conclusions

The conclusions are divided up into a general evaluation of the (theoretical) findings. Thereafter the overall prediction presented earlier is tested. Finally, the outcome and benefits of the work according to the author's judgement are outlined. The conclusions in Chapter 10 in Stenis (2002) have been found to be useful and are thus also used here to a certain extent.

5.1 Theoretical works

As regards the general industrial applicability, the theoretical findings point at the fruitful possibility to modify commonly used cost-benefit estimation methods including the PPP in an industrial waste management context by the use of the equality principle introduced. The elaborated theory is also shown to be suitable as a basis for e.g. voluntary environmental agreements. The literature study performed showed that business economic theory aspects in the waste management field being rare.

5.2 Practical applicability

As regards the general industrial applicability, as shown in the papers appended, the modification of the economic theory according to the equality principle introduced can be applied in estimating the profitability of fractionating industrial (solid) wastes. However, it is not possible to determine exactly to what extent all of the findings achieved are possible to apply in a practical and concrete context. Nevertheless, the current findings are based on prevailing and commonly known management theory. Therefore, they can be expected to have a high degree of applicability also in the real world.

In the purely corporate context, the use of business economic waste management model tools is a very rare phenomenon within major industry. Considering the substantial problems connected to residual products mismanagement, there undoubtedly exist a promising potential in the use of business economic waste management tools based on elaborated flexible waste management economic instrument models adapted to the changing societal demands.

As regards the construction waste management applicability, as shown in the construction site case study Opus 1, there exists a big potential for applying the equality principle introduced to a construction waste management context. The findings from the Opus 1 case study point in the direction of a high degree of construction waste management applicability in the real world industrial context due to the reasonable results that are obtained. In particular this statement is relevant for the average cost estimation method but also, to a much lesser extent, for the Polluter-Pays Principle application approach.

The applicability of the economic models that are studied is summarised in Table 5.1 with respect to the bulk product industry, mechanical industry and construction industry. The basis for the evaluation of the applicability is the reasonableness of the level of the shadow price allocated to the waste fraction in question in the case studies, respectively. The object of comparison is the current tipping fee (SEK 870 per tonne excluding VAT) for unsorted industrial, construction and demolition unsorted waste in September 2004, at the major

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Swedish waste management company SYSAV. This comparison is regarded as being one possible indicator among others of the real world usefulness of the scientific results that are obtained in this work.

Furthermore, the financial input information necessary for managers to apply the relevant modified economic models in practice, according to the results of the present work, with respect to bulk product industry, mechanical industry and construction industry, is summarised briefly in Table 5.2.

5.3 Overall prediction testing

According to the conclusions in 5.1 and 5.2, existing cost-revenue estimation methods, also in the PPP context, have been found capable of modification so as to make them practically applicable to the industrial preventive waste management area. In the case of the construction waste related theory, the method has also been found to a certain extent, to be also applicable in practice. The methods can thus probably provide a theoretical business economic basis for possible environmentally friendly industrial and construction waste management official recommendations and demands and/or voluntary environmental agreements. The findings, therefore, can be seen as a realistic alternative to traditional approaches based on taxation, fees and regulations. They can also change the attitudes towards industrial and construction waste and promote the use of e.g. profit-enhancing production processes that utilise waste in an environmentally friendly way. The prediction presented earlier in 2.1.4 can thus be said to be partly reasonably justified.

5.4 Outcome and benefits

This work presents an elaboration of a principle for estimation of waste related industrial company costs and revenues which constitutes the basis for estimation of the "full" company cost and estimation of the "true" company business financial result giving impact on the related consolidated profit and loss account, budgets and forecasts etcetera. This is a result of the general application of the equality principle introduced as a basis for e.g. waste related official recommendations and demands and voluntary environmental agreements. The outcome and benefits from the present study are summarised in Table 5.3 as regards: a) companies, b) the environment and c) society.

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Table 5.1. The applicability of the economic models that are studied in the present work with respect to the bulk product industry, mechanical industry and construction industry, rated from the lowest rating: "---", to the highest rating: "+++", as regarding the shadow price, given as USD per tonne, allocated to the waste fraction in question in the case studies, respectively. The object of comparison is the current tipping fee (USD 113 per tonne = SEK 870 per tonne) excluding VAT of unsorted industrial, construction and demolition waste in September 2004, at the major Swedish waste management company SYSAV. (An exchange rate of USD 1 = SEK 7.70 is assumed throughout.)

Model	Bulk product industry	Mechanical industry	Construction industry
I. Cost-benefit analysis			
1. Method of overhead rates based on normal capacity	+++ (USD 327)	---	---
2. Average cost estimation method	+++ (USD 327)	---	+++ (USD 94)
3. Equivalent method of cost estimation	+++ (USD 226)	---	---
4. Absorption costing method	+++ (USD 301)	+ (USD 3731)	--
5. Activity-Based Costing (ABC) method	+++ (USD 630)	+ (USD 8615)	--
6. Remainder method	---	---	---
II. Contribution margin analysis method	+++ (USD 327)	++ (USD 2000)	---
III. The Polluter-Pays Principle (PPP)	++ (USD 4)	+ (USD 0.6)	+ (USD 0.02)

Table 5.2. Summary of the necessary financial input information when managers are to apply the relevant modified economic models according to the results of the present work with respect to bulk product industry, mechanical industry and construction industry. (TR = Total Revenue, FC = Fixed Costs, VC = Variable Costs, TC = Total Costs, NPV = Net Present Value).

Model	Bulk product industry	Mechanical industry	Construction industry
I. Cost-benefit analysis			
1. Method of overhead rates based on normal capacity	TR of the waste fraction and FC and VC of the production unit.		
2. Average cost estimation method	TR of the waste fraction and FC and VC of the production unit.		TC of the waste fraction and TC of the production unit.
3. Equivalent method of cost estimation	TR of the waste fraction and FC and VC of the production unit.		
4. Absorption costing method	TR of the waste fraction and TC of the production unit.	TR of the waste fraction and TC of the production unit.	
5. Activity- Based Costing (ABC) method	TR of the waste fraction and TC of the production unit.	TR of the waste fraction and TC of the production unit.	
6. Remainder method			
II. Contribution margin analysis method	Income from sales, FC and VC of the fraction sold.	Income from sales, FC and VC of the fraction sold.	
III. The Polluter-Pays Principle (PPP)	The environmental adjustment cost and NPV of the investment.	The environmental adjustment cost and NPV of the investment.	The environmental adjustment cost and TC of the waste fraction and TC of the production unit

Table 5.3. Outcome and benefits of the present work as regards a) companies, b) environment and c) society.

Outcome and benefits of the present work as regards companies
1. Elaboration of a principle for the estimation of waste-related industrial company costs and revenues.
2. Establishment of a basis for the estimation of the "full" company cost and estimation of the "true" company business financial result.
3. Implications of industrial cost-saving incentives.
4. Improvement of the short-term, corporate economy generally.
5. Saving of raw materials, less reduction in time required for handling and less administration of the waste and less wear on the machinery, etc.
6. A positive impact on the balance sheets due to improved environmental goodwill.
7. Enhanced status of industrial and construction waste.
8. Possible increase in the use of prefabricated and made-up construction material leading to higher profits and better quality.

Outcome and benefits of the present work as regards the environment
1. Less waste produced due to reduction in the current wastes at the source.
2. More environmentally friendly industrial production.

Outcome and benefits of the present work as regards society
1. A basis for e.g. waste-related official recommendations and demands, and voluntary environmental agreements.
2. A generally improved environment leading to an improved quality of life.
3. An environmentally improving increase in the gross domestic product (GDP).
4. An attempt to provide the part of society interested in waste management with an economic review theory adapted to industrial and construction waste management.
5. A pioneering attempt as to launch a proposal for a shift in the view of waste management.
6. General environmental and financial advantages for society at large.

These new principles for industrial cost allocation to industrial residual products are therefore very likely to imply industrial cost saving incentives through the introduction of inter alia new improved source reduction production technology. The connected reduction of the current wastes at the source in total leads to less waste produced. As a direct result the short term corporate economy generally is improved through the saving of raw materials, less time necessary for handling and less administration of the waste and less wear of the machinery etc. Further environmental aspects connected to business economy are that in the more long-term perspective, extended environmental goodwill from adequate waste management will give a positive impact on the balance sheets. This will be based on an enhanced status of industrial and construction waste, due to a new way of looking at such waste as equalised with regular products in financial terms. As a final overall goal accomplished, generally improved environment will be the result, leading to an improved quality of life.

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Regarding economics at the national level and EU-related possibilities with respect to co-ordinated environmental work, in particular concerning voluntary environmental agreements all over Europe, an environmentally improving raise in the gross domestic product (GDP) per capita will come about due to profit increasing improvements in waste management.

The work can be seen as an attempt to provide the waste management interested part of society with an industrial and construction waste management adapted economic theory review as well as with modifications of certain currently used economic methods. Hence, to a certain extent, the present work represents a pioneering attempt in that it is a proposal for a shift of waste management views.

However, it should be remembered that sometimes a minimum of wastes produced may induce an inefficient working situation since extra jobs occur when the source separation is performed on e.g. a construction site. This will increase the labour cost. A concrete positive thing with a minimum of wastes produced is that the use of prefabricated and made-up construction materials may increase. This may give bigger profits and better quality, hopefully combined with a more environmentally friendly production.

Also, to manage the industrial and construction waste handling may result in, except from assort, to an increase as well as a decrease in the amount of wastes produced. This is so since, for example, waste management companies make money on taking care of wastes and therefore may want as much waste as possible to be produced. What is favourable in one aspect may be disadvantageous in another as regards the industrial as well as the construction waste management context.

Hopefully, this thesis will contribute to further debate concerning what can be regarded as an appropriate waste management policy. In any case, it is hoped that the overall knowledge of the interested reader concerning waste management has been enhanced.

6 Further research

This chapter presents an outline of possible avenues for further research based on the current findings.

Sustainable building indicators

A field of research that has lately attracted a certain amount of attention is the development of sustainable building indicators. These may be based on the principle for equality between residual products and goods in mainly financial terms developed earlier. It would be suitable to investigate how the equality principle, in the design stage as well as during the erection and operation of a building, can be used for monitoring the sustainable flow of resources through the building in order to increase the efficiency. In particular, the possibilities to develop indicators for waste (reused, recycled, energy production, disposal and special waste) should be studied. Thereby, a situation is assumed to prevail where the contractor and not the owner has the responsibility for the erection of the building in question. This implies good opportunities to, based on the equality principle, for applying in practice sustainable building indicators that are relevant, sensible, objective, measurable, accessible and readable.

Modification and application of management tools

Industrial and other kinds of waste must as much as possible be minimised in order to achieve a clean enough environment in accordance with the eco-cycle philosophy. This implies a new look on different kinds of waste; a shift of views and a change of attitudes is a necessity in order to make the waste phenomenon be regarded as equal to ordinary goods and other facilities primarily with respect to the allocation of costs. This point of view is denoted "the equality principle" (Stenis, 2002). Existing models for waste management usually lack clear financial incentives for implementation of waste reducing means of control. Therefore, the question is how existing theoretical management tools can be modified and applied regarding a general need to reduce the existence of the waste phenomenon through giving the different actors strong financial incentives to implement a sustainable waste policy. The main purpose in this context would be to show how the mainly prevailing management tools, methods and models can be adapted according to the equality principle with the aim of laying the foundation for design of new control devices for implementation of sustainable official authority policies for management of resources and wastes in order to improve the environment. Generally, the concept advocated here is to efficiently contribute to a reduction of the misuse of resources in society. The possibilities to apply such research efforts are thought to exist for material resources as well as for the energy sector, the interest in, for example, industrial waste as a source for reuse and recycling of material and energy resources having increased during recent years (Stenis, 2001).

Principles for construction object disassembly for reverse logistics

A field of research that is more directed towards the end of the lifetime of a building is so called reverse logistics. Generally, reverse logistics refers to all logistic activities to collect, disassemble and process used product parts, and/or materials in order to ensure a sustainable (environmentally friendly) recovery (RevLog, 2004). In this study, this term refers to the time when a construction object is disassembled and the different components must be taken care of, this involving a substantial logistical effort to organise the transportation of the

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different parts to their final destinations. Therefore, it should be studied how concrete principles for construction object disassembly can be elaborated in order to make the reverse logistics process more efficient based on the equality principle introduced (Stenis, 2002).

Application of the equality principle on different types of construction objects

Finally, it would be worthwhile to examine the economic consequences that occur when the equality principle, primarily through the average cost estimation method, is applied to other construction objects than ordinary houses, examples being industry buildings and infrastructural objects. However, the effects can be expected to be rather constant due to the general applicability of the equality principle to waste producing activities.

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