Designing Collection Rate Enhancing Measures for ‘Small’ Consumer Electronics

PROEFSCHRIFT

ter verkrijging van de graad van doctor aan de Technische Universiteit Eindhoven, op gezag van de Rector Magnificus, prof.dr. R.A. van Santen, voor een commissie aangewezen door het College voor Promoties in het openbaar te verdedigen op donderdag 20 februari 2003 om 16.00 uur

door

Frans Melissen

geboren te Oudenbosch

Dit proefschrift is goedgekeurd door de promotoren:

prof.dr.ir. A.C. Brombacher
en
prof.drs. G.H.J. Keijzers

Copromotor:
dr.ir. A.J. de Ron

CIP-DATA LIBRARY TECHNISCHE UNIVERSITEIT EINDHOVEN

Melissen, Frans

Designing collection rate enhancing measures for 'small' consumer electronics / by Frans Melissen. – Eindhoven : Technische Universiteit Eindhoven, 2003. – Proefschrift. -

ISBN 90-386-1987-1

NUR 973

Keywords: Collection rates / Consumer electronics / Disposal structures / Policy measures / Take-back legislation

Technische Universiteit
Eindhoven

Department of
Technology Management

“You cannot solve problems with the same type of thinking that caused them”

interpretation of Einstein

by

Prof.dr. N. Douben
(technologische) innovaties de maat genomen
November 22, 2002
Techn. Univ. Eindhoven
ISBN 90-386-1442-X

Preface

This thesis is the result of my assignment as a research assistant in the Department of Technology Management of the Eindhoven University of Technology. I would like to use this opportunity to thank all who have contributed to my work.

My special thanks go to a few people that I will mention here:

First of all I would like to thank my supervisors, prof. Brombacher and prof. Keijzers. I would also like to thank prof. Sander and prof. Midden for their role as additional supervisors. My special thanks go to my copromotor Ad de Ron, for all his help and support, and his companionship throughout the years.

I would also like to thank my colleagues at the University, especially the members of the capacity group Quality of Products and Processes.

Finally, I thank the most important people in my life: my parents and Lotte. The three of you are the reason that I consider myself to be a 'lucky dog.'

Frans Melissen
Eindhoven, December 2002

Summary

This thesis is based on a research project that was one of four subprojects included in a so-called IOP-project (Innovation-driven Research Programmes) that was sponsored by the Dutch Department of Economic Affairs. The mainspring for this project, and the introduction of take-back legislation in a number of countries, was the observation that consumer electronics play an important role in the increase of heavy metals in the environment. The uncontrolled dispersion of these heavy metals constitutes a substantial (public) health risk.

The above-mentioned IOP-project aims at contributing to closing the life cycle of heavy metals in consumer electronics by simultaneously addressing the design of consumer electronics, recycling techniques, and the way the disposal structure for these products is organised, equipped and managed. This thesis deals with the collection stage, especially the effects of specific collection schemes on the collection rates for end-of-life products, within the disposal structure for consumer electronics in the Netherlands.

Chapter 1 of this thesis presents an overview of literature dedicated to disposal structures and reveals that, even though collection costs comprise a substantial contribution to the overall end-of-life management costs for discarded products and optimal planning of disposal structures is hampered by the high uncertainty of the input (the number of collected products), researchers in this field still tend to focus on the clear-cut topic of location-allocation problems and seem to neglect the stage that is causing many problems; the collection stage.

The fact that the collection stage of disposal structures in practice can cause serious problems is illustrated in Chapter 2, which analyses the current situation with respect to consumer electronics in the Netherlands. This analysis shows that ‘small’ consumer electronics contribute considerably to the unwanted dispersion of heavy metals to the environment, because a substantial portion of these products is in years disposed of by consumers by means of the refuse bag/bin for regular household waste. This means that these products end up in incineration facilities for regular household waste, which results in a number of leakages of heavy metals to the environment and pollution of incinerator residues, which considerably reduces the number of available useful applications and requires additional (and costly) environmental precautions.

Resolving these (environmental) problems requires the separate collection and environmentally sound treatment of this product category.

Unfortunately, the introduction of specific take-back legislation (formulating a number of restrictions and regulations that should ensure the separate collection and treatment of consumer electronics) and the current disposal structure for consumer electronics in the Netherlands in practice that has originated from this legislation have not prevented consumers from persisting in their long since habit of throwing ‘small’ appliances in the refuse bag/bin. Therefore, additional (policy) measures are required. Consequently, this

thesis focuses on designing such (collection rate enhancing) measures and the various stages of this design effort are explained in Chapter 3.

As a first step in the analysis stage of this design effort, Chapter 4 describes a number of pilot projects dedicated to the collection of discarded 'small' consumer electronics and derives the lessons that can be learned from these case studies. Subsequently, Chapter 5 focuses on empirical findings and theoretical perspectives presented in available research and literature dedicated to the determinants of human (disposal) behaviour, in order to establish the shortcomings of the current disposal structure for consumer electronics in the Netherlands and the essential elements that would need to be included in collection rate enhancing measures to be designed. The analysis reveals that disposal behaviour is not so much dependent on concepts like normative influence, pro-environmental attitudes and general environmental concern, but primarily determined by barriers and effort required, perceived costs and benefits, and past behaviour. The latter refers to the habitual nature of disposal behaviour and the fact that future behaviour often manifests itself in behavioural patterns that are based on an assessment, of effort required and costs and benefits, in the past. Therefore, influencing this type of behaviour not only requires measures to address these elements (barriers and costs/benefits), but also to 'grasp' the attention of consumers and spur them on to a reassessment of these elements. Chapter 5 introduces the Triad model, a psychological meta-model, as a means to analyse the current disposal structure for consumer electronics in the Netherlands with respect to all of these aspects. It is shown that the current collection system within this structure favours disposing of 'small' consumer electronics by means of the refuse bag/bin, as against disposing of these products by means of separate collection routes, especially with respect to the effort, costs and rewards involved. Therefore, it is not surprising that a substantial portion of these appliances still end up in the regular household waste stream. Consequently, collection rate enhancing measures to be designed need to address this problem.

Chapter 6 of this thesis is dedicated to generating design alternatives for these measures (the synthesis stage of the design effort) by applying the Morphological Chart Method, and based on the findings of the analysis stage (Chapters 4 and 5). These design alternatives encompass a set of provisions that aim at making the desirable behavioural alternative (separate collection) more attractive to consumers than the undesirable alternative (refuse bag/bin). An additional alternative is generated that represents the current strategies, applied by the Dutch government and other parties involved, to enhance collection rates for consumer electronics. The central element of these strategies is formed by promotional campaigns that appeal to a voluntary change of behaviour by consumers based on an awareness of shared responsibility.

All of these design alternatives are evaluated in Chapter 7 with respect to the expected economic and environmental consequences and the practical feasibility of effectuating these measures. It is concluded that the highest collection rates can be achieved by means of a collection rate enhancing measure that encompasses, among other things, the following set of provisions:

- Adjusting local taxes based on the amount of 'small' consumer electronics detected in regular household waste during waste analyses of representative samples.

- Situating collection points for ‘small’ consumer electronics at supermarkets, analogous to the already existing collection points for deposit money bottles.
- Distributing special carrier bags that can be used to store and transport these appliances.
- Introducing a lottery based reward system.
- Extensive promotional campaigns that emphasise the rewards and the increased convenience of handing in end-of-life products.

However, this design alternative also involves higher running costs than the current strategies. Therefore, the ultimate political dilemma that ensues from the design effort presented in this thesis amounts to a choice between environmental consequences and financial consequences. Collection rates for ‘small’ consumer electronics can be enhanced, but the choice to do so signifies the need for additional investments (money and effort) to achieve this objective.

Unfortunately, at this point it is not obvious what party would be the proper authority to make this choice and initiate this measure. Chapter 8 shows that the allocation of responsibilities within the current disposal structure for consumer electronics in the Netherlands does not clearly attribute the responsibility for addressing the low collection rates for ‘small’ appliances. In fact, one could even argue that for two of the main parties involved, municipalities and producers, it would not be in their best interest to promote appropriate disposal behaviour by consumers. This would only result in higher workloads and working expenses, while not resulting in any clear advantages. The analysis in this Chapter addresses this dilemma in more detail and ultimately establishes the clear responsibility of the Dutch government with respect to the choice mentioned above and managing the actual effectuation in practice of any collection rate enhancing measure. A final discussion with respect to this particular topic reveals that failing to do so now could even make it more difficult to solve environmental problems, such as the health risks that result from the faltering collection stage in the current disposal structure for consumer electronics in the Netherlands, in the long run.

Samenvatting (summary in Dutch)

Dit proefschrift is gebaseerd op de uitkomsten van een onderzoek dat deel uitmaakte van een zogenaamd IOP-project (innovatiegerichte onderzoeksprogramma's, gesponsord door de Nederlandse overheid). De reden voor het opzetten van dit project, en tegelijkertijd de reden voor het introduceren van recyclingwetgeving in vele landen, was de constatering dat consumentenelektronica een belangrijke bijdrage leveren aan de toename van zware metalen in het milieu. De ongecontroleerde verspreiding van deze zware metalen leidt tot ernstige gezondheidsrisico's.

Het bovengenoemde IOP-project richt zich op het leveren van een bijdrage aan het sluiten van de levenscyclus van zware metalen in consumentenelektronica door aandacht te besteden aan de ontwerpfase, recycling technieken en de manier waarop de terugwinketen voor deze producten wordt georganiseerd, gemanaged en uitgerust. Dit proefschrift richt zich op de inzamelingsfase, met name de effecten van specifieke inzamelingsvoorzieningen op de hoeveelheid ingezamelde producten (inzamelingspercentage) binnen de terugwinketen voor consumentenelektronica in Nederland.

Hoofdstuk 1 geeft een overzicht van literatuur op het terrein van terugwinketens. Ondanks de constatering dat inzamelingskosten een substantieel deel uitmaken van de totale kosten gemoeid met het terugwinnen en verwerken van afgedankte producten en het feit dat het optimaliseren van terugwinketens ernstig belemmerd wordt door onzekerheid ten aanzien van de input (hoeveelheid ingezamelde producten), richten wetenschappers zich met name op klassieke logistieke probleem (allocatie en reallocatie) en lijken zij de fase die vele problemen veroorzaakt te negeren; de inzamelingsfase.

Het feit dat de inzamelingsfase binnen terugwinketens in de praktijk grote problemen kan veroorzaken wordt geïllustreerd in hoofdstuk 2, waarin de huidige situatie met betrekking tot consumentenelektronica in Nederland wordt geanalyseerd. Deze analyse toont aan dat 'kleine' consumentenelektronica een belangrijke bijdrage leveren aan de ongewenste verspreiding van zware metalen in het milieu, omdat deze apparaten sinds jaar en dag in de vuilnisbak belanden. Dit betekent dat zij uiteindelijk in verbrandingsovens voor huisvuil terechtkomen, wat weer resulteert in verschillende 'lekkages' naar de omgeving en vervuiling van de verbrandingsslakken. Deze slakken kunnen daardoor niet meer nuttig toegepast worden en de opslag ervan vereist allerlei additionele (en kostbare) milieubeschermende maatregelen.

Het voorkomen en oplossen van bovenstaande problemen vereist het apart inzamelen en milieuverantwoord verwerken van deze categorie producten.

Helaas hebben specifiek daarop gerichte wetgeving (waarin verplichtingen en voorschriften voor het apart inzamelen en verwerken van deze producten worden vastgelegd) en de daaruit voortvloeiende terugwinketen in de praktijk (in Nederland) niet kunnen voorkomen dat de meeste burgers nog steeds volharden in hun gewoonte om kleine apparaten in de vuilnisbak/zak te gooien. Aanvullende maatregelen zijn dan ook nodig. In hoofdstuk 3 van dit proefschrift wordt daarom een aanzet gegeven tot een ontwerpproces dat zich richt op

het ontwikkelen van dergelijke (inzamelingsbevorderende) maatregelen. In het vervolg van dit proefschrift wordt dit proces nader uiteengezet.

De eerste fase in een dergelijk ontwerpproces bestaat uit een nadere analyse van het probleem en mogelijke oplossingen. In hoofdstuk 4 wordt daarom een aantal proefprojecten op het terrein van de inzameling van 'kleine' consumentenelektronica behandeld. Hoofdstuk 5 richt zich vervolgens op empirische gegevens en theoretische uitgangspunten in bestaande literatuur op het terrein van (afdank-) gedragsdeterminanten, om de tekortkomingen van de huidige terugwinketen in de Nederlandse praktijk te kunnen vaststellen. Daarnaast wordt ingegaan op de gedragsaspecten die in ieder geval deel uit moeten maken van inzamelingsbevorderende maatregelen. Deze analyse toont aan dat afdankgedrag niet bepaald wordt door concepten als normatieve invloed, milieubesef en milieukennis, maar veel meer door belemmeringen en de vereiste inspanning, kosten en opbrengsten, en gedrag in het verleden. Dat laatste aspect heeft betrekking op het feit dat afdankgedrag vaak gewoontegedrag is en dat toekomstig gedrag vaak voortvloeit uit gedragspatronen die gebaseerd zijn op een eerdere afweging van de vereiste inspanning en de kosten en opbrengsten. Deze afweging wordt niet steeds opnieuw gemaakt. Daaruit volgt dan ook onmiddellijk dat het beïnvloeden van dergelijk gedrag niet alleen vraagt om het veranderen van de vereiste inspanning en de kosten/baten verhouding, maar ook om maatregelen die de aandacht trekken en die burgers aansporen tot het opnieuw maken van een dergelijke (nieuwe) afweging. Hoofdstuk 5 introduceert daarom het Triade-model, een psychologisch denkmodel, dat een mogelijkheid biedt om al deze aspecten mee te nemen in een analyse van de huidige terugwinketen voor consumentenelektronica in Nederland. Op grond van deze analyse wordt vastgesteld dat de huidige voorzieningen op het terrein van inzameling binnen deze keten er voor zorgen dat het in de vuilnisbak gooien van kleine apparaten veel aantrekkelijk is voor burgers dan het apart inleveren. Het is niet alleen veel gemakkelijker, het is ook nog eens goedkoper en heeft verder helemaal geen negatieve gevolgen. Het is dan ook niet verwonderlijk dat het grootste deel van deze apparaten in de vuilnisbak belandt. Inzamelingsbevorderende maatregelen dienen zich daarom te richten op het veranderen van deze verhouding.

Hoofdstuk 6 richt zich op het generen van ontwerpalternatieven voor deze maatregelen met behulp van de zogenaamde Morfologische Kaartmethode en op basis van de uitkomsten van de analyse-fase (Hoofdstuk 4 en 5). Deze ontwerpalternatieven bestaan steeds uit een combinatie van voorzieningen die er voor moeten zorgen dat het gewenste gedrag (apart inleveren) aantrekkelijker wordt voor burgers dan het ongewenste gedrag (vuilnisbak). Aan deze ontwerpalternatieven wordt een extra alternatief toegevoegd dat bestaat uit het geheel van maatregelen dat tot nu toe door de Nederlands overheid en andere partijen wordt toegepast ter bevordering van de inzameling van consumentenelektronica. De meeste van deze maatregelen bestaan uit reclamecampagnes die een beroep doen op het verantwoordelijkheidsbesef van burgers.

Al deze ontwerpalternatieven worden vervolgens geëvalueerd op basis van drie criteria: kosten, milieuwinst en praktische haarbaarheid. Uit deze evaluatie volgt dat het verhogen van de inzamelingspercentages voor kleine apparaten het beste gerealiseerd kan worden door het invoeren van een maatregel die bestaat uit de volgende voorzieningen/acties:

- Lokale belastingen aanpassen op basis van het aantal kleine apparaten dat wordt aangetroffen in steekproeven van ingezameld huisvuil.

- Inleverpunten voor ‘kleine’ consumentenelektronica in supermarkten, analoog aan de inleverpunten voor statiegeldflessen.
- Het uitdelen van speciale draagtassen voor het bewaren en meenemen van kleine apparaten.
- Het belonen van burgers voor het inleveren van apparaten door middel van het overhandigen van een lot voor een loterij (bijvoorbeeld een kraslot).
- Een uitgebreide voorlichtingscampagne, met name gericht op het bekend maken van de loterij en het feit dat inleveren nu veel makkelijker is geworden.

Het invoeren van deze maatregel gaat echter wel gepaard met hogere kosten dan de huidige strategie. Dit leidt dan ook tot de constatering dat het ontwerpproces in dit proefschrift een politiek dilemma bloot legt: de keuze tussen milieuwinst en geld (kosten). De inzamelingspercentages voor kleine apparaten in Nederland kunnen wel degelijk verhoogd worden, maar dat vereist dan wel een verhoging van de investeringen (in geld en moeite) op dit terrein.

Helaas is het op dit moment niet erg duidelijk wie het initiatief zou moeten nemen tot een dergelijke investering. Hoofdstuk 8 gaat daarom in op de verdeling van verantwoordelijkheden binnen de huidige terugwinketen voor consumentenelektronica in Nederland en daaruit volgt dat er eigenlijk niemand verantwoordelijk is voor de hoeveelheid ingezamelde apparaten. Het is zelfs aannemelijk te maken dat de twee hoofdrolspelers in deze keten, gemeenten en producenten, niet gebaat zijn bij hogere inzamelingspercentages. Dat zou namelijk alleen maar leiden tot meer werk en hogere kosten voor deze partijen, zonder dat daar duidelijke voordelen aan verbonden zijn. Een nadere analyse in dit hoofdstuk toont aan dat de Nederlandse overheid dan ook de aangewezen partij is om het voortouw te nemen bij het beslissen over en het daadwerkelijk invoeren van inzamelingsbevorderende maatregelen. Dit proefschrift wordt afgesloten met een analyse ten aanzien van deze verantwoordelijkheid van de Nederlands overheid. Daaruit volgt dat het niet nakomen van deze verantwoordelijkheid op de langere termijn wel eens zou kunnen leiden tot het bevorderen van milieuonvriendelijk gedrag door burgers en daarmee zou het voorkomen/oplossen van milieuproblemen alleen nog maar moeilijker worden.

Table of contents

Chapter 4: Enhancing collection rates for 'small' consumer electronics
Empirical data derived from literature

Chapter 5: Enhancing collection rates for 'small' consumer electronics
Deriving theoretical perspectives from literature and reference points for the design process

Chapter 6: The synthesis stage
Generating design alternatives for collection rate enhancing measures

Chapter 1

Introduction, context and overview

1.1 Introduction

Setting the stage for this thesis is easy; it merely requires quoting the first sentences of some typical publications in the (still) emerging field of environmental research:

> *"The environmental revolution has been almost three decades in the making, and it has changed forever how companies do business." [Hart, 1997]*

> *"Environmental concerns are becoming more important in industry and business. One of the major issues today is how to dispose of waste. Collection and recycling of post-consumer waste in a cost-efficient manner is of increasing interest in business as well as in research." [Jahre, 1995]*

> *"The efficient recovery of materials used to manufacture and deliver products is the foundation of any waste prevention strategy." [Guide et al., 1997]*

> *"The challenge of industrial recycling, regardless of the material, is collection." [Witt, 1997]*

> *"Efficient planning and management of household waste recycling schemes demands an insight into how customers will respond to the scheme and how they will react to any management interventions that are designed to promote or sustain its performance." [Tucker et al., 1998]*

This thesis deals with the collection stage, especially the effects of specific collection schemes on the collection rates for end-of-life products, within the Product Recovery Network for consumer electronics in the Netherlands. In this thesis, the term Product Recovery Network (PRN) is adopted to describe ([Melissen & de Ron, 2001], also see Section 1.3):

> *"A structure of activities, consisting of physical locations, facilities, processes, actors and their functions, and transportation links, aimed at conveying used products from being set free by their former users to being (partially) re-used, incinerated, or land filled."*

The choice for this topic is based on three observations:

1. Despite the increasing relevance, relatively little research and few publications have been dedicated to this specific topic (also see Section 1.3).
2. The latter stages (actual processing of discarded products) of Product Recovery Networks for end-of-life products have been addressed extensively in research and

publications throughout the last few decades. In recent years however, 'major improvements' have become very rare and this could be interpreted as a sign that further advances in optimising Product Recovery Networks could benefit more from addressing the earlier stages of these networks (also see Section 1.3).

3. Recent studies have shown that actual collection rates for ('small') consumer electronics in the Netherlands are (far) below expected collection rates (see e.g. [PriceWaterhouseCoopers, 2001]). This situation amounts to lagging environmental gains of the current Product Recovery Network (also see Chapter 2).

Following this introduction, Section 1.2 explains the background and organisation of the research project that formed the basis for this thesis and provides a (scientific) characterisation of the project. As a first step in exploring the *project context* [Verschuren & Doorewaard, 1999], Section 1.3 discusses other research and publications dedicated to subject matters related to the topic of this thesis. Section 1.4 concludes this first Chapter by presenting an overview of the contents of the remainder of this thesis.

1.2 Background and (scientific) characterisation of the research project

This thesis is based on a research project that was one of four subprojects included in a so-called IOP-project (Innovation-driven Research Programmes) that was sponsored by the Dutch Department of Economic Affairs. The mainspring for this project, and the introduction of take-back legislation in a number of countries (see Chapter 2), was the observation that consumer electronics play an important role in the increase of heavy metals in the environment[1]. The uncontrolled dispersion of these heavy metals[2] constitutes a substantial (public) health risk [Staatsblad 238, 1998].

The above-mentioned IOP-project aims at (it is still going on) contributing to closing the life cycle of heavy metals in consumer electronics by simultaneously addressing the design of consumer electronics, recycling techniques, and the way the Product Recovery Network is organised, equipped and managed.

For the particular research project on which this thesis is based the following general objective was defined (by the initiators of the project) [Brombacher & De Ron, 1998]:

"To contribute to closing the life cycle of consumer electronics, especially with respect to heavy metals, by developing new concepts for organising and managing the Product Recovery Network for consumer electronics (in the Netherlands) that could contribute to optimising this network from a business economic and environmental perspective."

[1] See [Ansems & Van Gijlswijk, 2002] for a detailed analysis of the magnitude of these 'leakages.'

[2] The most important heavy metals (within consumer electronics), with respect to this health risk, are: Be, Hg, Cd, As, Se, Cr, Sb, Cu, Pb, Zn [Ansems & Van Gijlswijk, 2002].

Obviously, this means that this particular research project represents a *practice-oriented research* and the above-mentioned original objective and the overall objective of the IOP-project represent a first (general) description of the *project context* [Verschuren & Doorewaard, 1999].

The first step in such a practice-oriented research is to carry out a problem analysis to explore the project context in order to define an appropriate *project research objective*, which establishes the specific *contribution* that this thesis aims to make to the attainment of the objectives mentioned above [Verschuren & Doorewaard, 1999].

This exploration of the project context is the topic of the next Section in this Chapter, which discusses research and publications dedicated to subject matters related to this project context, and Chapter 2, which analyses the current Product Recovery Network for consumer electronics in the Netherlands in practice and its economic and environmental consequences.

This exploration has resulted in establishing the following *project research objective* for the project on which this thesis is based:

"To design appropriate measures for fine tuning the junction between consumers that set free used consumer electronics and the Product Recovery Network that absorbs and processes these products, in order to enhance collection rates, especially with respect to 'small' products."

The above represents a clear adjustment of the focus and design of the research project in comparison to the original research approach that was proposed at the start of the project [Brombacher & De Ron, 1998]. The reasons for this adjustment, based on the exploration of the project context, are explained in more detail in Chapter 3 of this thesis. Ultimately, this thesis represents a practice-oriented research that encompasses a *design-oriented research* that focuses on designing collection rate enhancing measures for 'small' consumer electronics.

The problem that is studied in this thesis, and for which a solution is designed, can be summarised as follows:

'Small' consumer electronics contribute considerably to the unwanted dispersion of heavy metals to the environment, because a substantial portion of these products is in years disposed of by consumers by means of the refuse bag/bin for regular household waste. This means that these products end up in incineration facilities for regular household waste, which results in a number of leakages of heavy metals to the environment (see [Ansems & Van Gijlswijk, 2002]) and pollution of incinerator residues, which considerably reduces the number of available useful applications and requires additional (and costly) environmental precautions [Staatsblad 238, 1998; Ansems & Van Gijlswijk, 2002].

Resolving these (environmental) problems requires the separate collection and environmentally sound treatment of this product category.

Unfortunately, the introduction of specific take-back legislation (formulating a number of restrictions and regulations that should ensure the separate collection and treatment of

consumer electronics [Staatsblad 238, 1998]) and the current Product Recovery Network for consumer electronics in the Netherlands in practice that has originated from this legislation have not prevented consumers from persisting in their long since habit of throwing 'small' appliances in the refuse bag/bin. Therefore, additional (policy) measures are required.

1.3 A survey of relevant literature

A growing number of publications dedicated to environmental issues related to business activities has emerged in scientific literature in the last few decades. Gungor & Gupta [1999] have published an extensive overview of the up-to-date literature in this field, which they denominate "Environmentally Conscious Manufacturing and Product Recovery (ECMPRO)." They distinguish two commonly accepted primary objectives of research in this field: (1) create environmentally friendly products; and (2) develop techniques for product recovery and waste management. In order to realise these objectives, a number of specific topics should be addressed, such as: Life Cycle Analysis, Design for Environment, Environmentally Conscious Manufacturing, pollution prevention and waste management, collection, and issues related to materials and product recovery.

The paper by Gungor & Gupta is intended "...to be as thorough as possible by covering most of the subject matter relevant to ECMPRO." It covers a wide range of published work in this area and therefore, this Section will not try to surpass or repeat their effort. However, this Section is intended to give a short impression and characterisation of literature in this field and identify potentially valuable publications and weaknesses in literature with regard to the topic of this thesis (see Section 1.2). For that purpose, the work by Gungor and Gupta forms an excellent 'starting point.'

1.3.1 A general overview of literature in the field of ECMPRO

The following two quotations from Gungor & Gupta [1999] could be considered to be 'typical' for publications dedicated to environmental topics:

> "We envision the environment as a flower. The flower is being threatened for extinction. The topics in ECMPRO are the stamens of the flower. The survival of the flower depends on the survival of the stamens. If the stamens of the flower die or are not spread, the flower (environment) will become extinct. Thus, it is imperative that we preserve the stamens (i.e. follow good ECMPRO practices) in order to leave healthy flowers (environment) for our next generation."
>
> "Although ECMPRO research is still in its infancy..."

These two statements give a good impression of literature in this field. Most publications kick off their argument by stressing the enormous importance of the underlying topic, explaining the ever-increasing threat of "highly visible ecological problems" [Walley & Whitehead, 1994], referring to the need for a "liveable planet" [Hart, 1997], and indicating the role of companies in bringing about these problems. After that characteristic

introduction, focus usually shifts quite swiftly towards a specific 'objective' problem within this field, and most often the 'adequate' solution is found and explicated.

Unfortunately, solutions are often only applicable in one specific situation and interactions between research efforts are rare, or as Gungor & Gupta [1999] put it: "... it is being conducted in clusters." Not seldom, one can find publications drawing opposite conclusions from empirical evidence. Where authors like Walley & Whitehead [1994] state that "as environmental challenges become more complex and costs begin to skyrocket, win-win solutions will become increasingly scarce," others claim the opposite, by stating that environmental opportunities might actually become a major source of revenue growth [Hart, 1997].

Publications in this field are often larded with "prophesying," which shows that for many of the authors the subject under investigation is no more and no less than a religion. Problem analysis and the identification of solutions have been accompanied by the introduction of a number of new terms, definitions, concepts, and 'clarifying' metaphors. In fact, the terms and concepts being employed could be said to have formed a "new linguistic and conceptual world, which lives a life of its own and has a tendency to be elitist" [Wolff, 1998]. This world is not only separated from others, and often unfathomable to non-initiated, it is confusing in itself.

At the same time, in sharp contrast with the abundant introduction of new concepts and theories that claim to incorporate the essence of all problems, research in this area seems to be going in circles, with self-proclaimed (and sustained) 'infancy' rounding off the argument of many publications. It is quite telling that Gungor & Gupta [1999] conclude their overview of the current state-of-the-art in ECMPRO research with the following statement:

> "The research effort is growing fast. However, from our review of the current state of the research on ECMPRO, we conclude that there is a lack of sufficient analytical research and a lot of work still remains."

However, at this point it is important to note that the characterisation of literature given in the foregoing paragraphs does not mean that research in this area is a lost cause. A number of authors have indeed published very insightful and valuable contributions with regard to environmental issues in general and the subject of this thesis in particular (i.e. Product Recovery Networks, especially the collection stage). The remainder of this Section is dedicated to discussing some of these contributions and identifying possible implications for this thesis, and at the same time establishing the blanks that need to be addressed in order to apply (some of) the findings of these authors in practice.

1.3.2 Product Recovery Networks

In the last few decades, a number of authors have addressed the 'technical' aspects of the latter stages in a Product Recovery Network. One of the first to do so was Robert T. Lund in his influential contribution "Remanufacturing" [Lund, 1984], in which he 'introduced' an alternative approach to dealing with discarded products than disposal. Following in his footsteps, many authors have analysed the various options available for processing specific

(types of) discarded products. Many have addressed this issue by describing "best practices" and industry examples, as illustrated in the overviews of literature by Gungor & Gupta [1999] and, more recently, Sarkis [2001]. Others have focussed on theoretically distinguishing the various "recovery options" [Thierry et al., 1995] and the affiliated appropriate nomenclature [Melissen & de Ron, 1999].

At this point, it is important to note that 'technical' aspects that could contribute to optimising a Product Recovery Network typically are very product specific. Furthermore, the 'technical' aspects of the latter stages in a PRN for consumer electronics are the topic of two of the other three subprojects within the framework of the IOP-project described in Section 1.2. Therefore, this topic will not be addressed here any further and the remainder of this Section focuses on the organisational and managerial aspects of a PRN.

Literature dedicated to the organisational and managerial aspects (or operations management) of Product Recovery Networks usually focuses on one of the following three domains within such a network: distribution planning, inventory management, and production planning [Fleischmann et al., 1997; Inman, 1999].

First of all, with respect to *production planning aspects*, a number of authors have developed methodologies and (decision support) models to determine the optimal recovery strategy [Krikke, 1998] (which combination of recovery options leads to the highest profit) and/or the optimal disassembly strategy [Penev, 1996; Johnson & Wang, 1995] (which components should be disassembled and the optimal sequence to do so). Others have focussed specifically on the problems related to applying MRP systems to plan recovery operations [e.g. Thierry, 1997] and possible solutions (by means of deterministic modelling) [e.g. Gupta & Taleb, 1994; Flapper, 1994; Clegg et al., 1995]. Another influential author in this particular field of research is V.D.R. Guide Jr., who has focussed specifically on the topic of shop floor control in remanufacturing [Guide, 1996; Guide et al. 1997<1/2>].

One of the major problems facing research in the area of production planning aspects in a product recovery network context is the high uncertainty of timing, quantity and quality of the input (the collected and distributed end-of-life products). While dealing with production planning aspects lies beyond the scope of this thesis, some of the outcomes of this thesis could form a contribution to this particular field of research by reducing the uncertainty of the quantity and timing of the input.

The second key area in research dedicated to organisational and managerial aspects of Product Recovery Networks deals with *inventory management* and this subject can be characterised as a "relevant research topic with many open questions" [Fleischmann et al., 1997]. A number of authors have introduced models to tackle this topic and these models can be classified into two major classes: (1) deterministic models, and (2) stochastic models.

In models of the first class, all demand and return flows are known in advance and the aim is to minimise the sum of the set-up and inventory costs (see e.g. [Schrady, 1967], [Mabini et al., 1992], and [Richter, 1996]).

The second class of models deals with demand and return flows as stochastic processes. Within this category, a large number of authors has dedicated publications to repair systems. With regard to this topic, interested readers are referred to literature reviews dedicated to this specific research area, since this lies beyond the scope of this thesis. A second group of models within this class is dedicated to "product recovery systems" [Fleischmann et al., 1997], and focuses on situations where demand and return flows are not directly linked and are considered to be independent stochastic processes. Some notable contributions in this field are those by Cohen et al. [1980], Inderfurth [1996, 1997], Heyman [1997], Muckstadt & Isaac [1981], and Van der Laan et al. [1996<1>, 1996<2>]. A more elaborate discussion on these contributions can be found in [Fleischmann et al, 1997] and [Gungor & Gupta, 1999].

With regard to these first two domains within a Product Recovery Network, it is impossible to address these issues separately from the technical issues concerning the latter stages of the network, the actual reprocessing of end-of-life products. Therefore, further discussions on this topic will form an important part of the fine-tuning of the four subprojects within the IOP-project described in Section 1.2. However, such a discussion lies beyond the scope of this particular thesis.

The third key domain of a Product Recovery Network, *distribution planning*, is the key topic of this thesis. Therefore, it is addressed in more detail than the proceeding two domains.

1.3.3 Distribution planning within Product Recovery Networks

This topic is often referred to as "reverse distribution" or "reverse logistics" [e.g. Carter & Ellram, 1998] and deals with the collection and transportation of end-of-life products. Similarly, a Product Recovery Network is often named a "reverse supply chain." The term "reverse" is related to the concept of "movement of goods from a consumer towards a producer in a channel of distribution" [Pohlen & Farris II, 1992]. However, the flow of end-of-life products does not always point to the (original) producer. Jahre [1995<1>] illustrates this by saying that "the materials flow from consumer back to the point where materials are available for reprocessing." In fact, Giuntini & Andel [1995] claim that we should think of reverse logistics as broadly as "an organization's management of materials obtained from customers," and Thierry [1997] states that "products from different types of return flow may have to be processed differently, i.e., using different Product Recovery options, depending on their quality, market demand, et cetera." Moreover, the actors involved in the "reverse distribution" of end-of-life products may be members of the forward channel (original producers, retailers, and logistics service providers), but can also come from outside this forward channel (e.g. material recovery facilities and specialised secondary material dealers) [Fleischmann et al., 1997]. Therefore, the term "network" gives a better description of the entirety of parties involved, and the term Product Recovery certainly gives a better impression of the variety of routes the end-of-life products can follow than simply employing the adjective "reverse." Hence, the choice for describing the topic under investigation in this thesis as a Product Recovery Network for consumer electronics.

Generally, the well-known article by Guiltinan & Nwokoye [1975], in which they identified four types of reverse channels, has been recognised as one of the first publications to

address (the organisational aspects of) distribution planning within Product Recovery Networks. This contribution formed the point of departure for work by authors like Pohlen & Farris II [1992], who laid the groundwork for distinguishing between various important actors in a Product Recovery Network, and the possibility to organise them in different combinations and structures, and let them perform various/different specific functions.

More recently, some very interesting publications in this field have been those by Marianne Jahre, who has dedicated considerable research efforts to analysing the collection systems for household waste. In her contribution to the First International Working Seminar on Reuse in Eindhoven [Jahre & Flygansvær, 1996] she presented a theoretical framework for analysing collection systems for electronic waste. This framework was based on an article by Mallen [1970, reprinted in 1996], in which he introduced a multi-stage process for selecting channels of distribution and suggests four main decisions concerning channel structure (number of distribution levels, number of middlemen, number of functions, and number of channels). This theoretical framework has been combined with distribution channel theory, a review of available literature, some preliminary case studies (seemingly of a qualitative nature) and "logic" to derive a number of (theoretical) propositions that refer to the relation between specific properties of the collection system (collection stage design alternatives) and the (financial and service) performance of the system [Jahre, 1995<1>]. In her PhD thesis [1995<2>], she also identified four main properties of reverse distribution channels (collection and distribution stages of a Product Recovery Network) that influence the performance. Chapter 3 addresses these properties in some more detail as part of a discussion with respect to the original research approach of the project on which this thesis is based.

Jahre applied her PhD thesis [1995<2>] and a later publication [Jahre, 1998] to present a "simulation model" to test the propositions mentioned above and to analyse cost consequences from changes in the (distribution planning) system and the environment (e.g. population density, waste stream characteristics).

Two other well-known authors that have dedicated research efforts to organisational and managerial aspects of distribution planning within Product Recovery Networks are Harold Krikke and Martijn Thierry.

In his PhD thesis [1998], Krikke focuses on two important managerial problems that need to be addressed in the set-up of a Product Recovery Network: (1) how to structure recovery from return flows, and, (2) where should which recovery and disposal processes be installed at what capacity, once the recovery strategy is known? After having determined how to handle forecast return flows in choosing the optimal recovery strategy for a particular situation (answer to question (1)), in the second part of his thesis, he presents a model for the (geographic) design of the distribution stage in a Product Recovery Network. In other words, he concentrates on developing a decision support model to assist managers in choosing "efficient locations and capacities to install processes and optimise good flows between the chosen locations."

Thierry dedicates his PhD thesis [1997] to examining "a variety of issues concerning Product Recovery Management and its impact on manufacturing companies in the electronics and car industries." After discussing the impacts of Product Recovery Management on production and operations management, and the requirements for the

production planning and control systems used by manufacturing companies following from the complexities involved with production and control in a Product Recovery Network, he discusses the so-called RevLog decision support system. This is a system set up to design and evaluate logistic networks for product recovery for (hypothetical) manufacturing companies in Europe. Basically, this system is designed to answer questions related to location (Where should a specific process step be executed?) and quantities (How many products/components should be processed in each of these locations?).

The most striking aspect (with regard to the topic of this thesis) of both of these models is that the flow of end-of-life products entering the distribution stage of a Product Recovery Network is treated as a given. Krikke states that he treats "the collection system and the reverse logistic system as independent sub-systems, where the collection system feeds the reverse logistics system" [Krikke, 1998]. Seeing that he opts for concentrating his research efforts on the latter, forecasts are needed on the resulting flow of collected end-of-life products entering the distribution stage of the Product Recovery Network. In his thesis, he deals with this problem by simply stating that "we assume that such forecasts are available" [Krikke, 1998]. The RevLog system, described by Thierry, has an even more straightforward way of dealing with this topic, by simply including the "product returns from market" [Thierry, 1997] as a parameter of the underlying model.

Several other authors have also proposed the application of modified facility location models to assist in distribution planning in Product Recovery Networks, e.g. [Mirchandani & Francis, 1989], [Caruso et al., 1993], and [Spengler et al., 1997].

Distribution planning within Product Recovery Networks is widely accepted as a very important and very complex research topic. This complexity "stems from the high degree of uncertainty inherent in the collection activities" [Gungor & Gupta, 1999]. Unfortunately, publications on this important and complex topic are "few and far between" [Fleischmann et al., 1997] and almost all of the models currently available in literature can be characterised as 'deterministic.' The problem of uncertainty with regard to the quantity and quality of collected end-of-life products is usually (explicitly) recognised, but dealt with, as illustrated in the preceding discussion on the work by Krikke and Thierry, by scenario and parametric analysis. In other words, the collection stage of a Product Recovery Network is treated as a "given."

Some other typical examples of this approach can be found in several contributions to the International Workshop on "Systems engineering models for waste management" in Göteborg, Sweden (1998). For instance, in the paper by Berger et al. [1998], dedicated to a decision support model called EUGENE, the following list of "givens" was presented as the necessary input for the model:

"Given: (1) the location of sources, (2) the generation of each type of waste from each source, (3) the various types of collections of waste, recyclables and organics ..."

All the above clearly illustrates a major flaw of current literature dedicated to distribution planning within Product Recovery Networks. It is recognised that "collection costs are known to contribute significantly (estimates range from 30 up to more than 50%, depending on specific conditions and definitions applied) to the overall end-of-life product management costs, and should therefore be minimised" [Mulder, 1999]. Moreover, many

authors state that they realise that “the actual quantity that is collected has to be the basis of the dimensioning of redistribution systems and the layout of dismantling, reconditioning and reprocessing plants” [Hansen, 2000]. Curiously though, researchers in this field still tend to focus, for whatever reason, on the clear-cut topic of location-allocation problems, even if this means stepping away from reality by introducing oversimplifying assumptions and presuppositions. In fact, the stage that is causing much of the problems they encounter in their modelling efforts, i.e. the actual collection stage of a Product Recovery Network, seems to be neglected, thus considerably reducing the practical value and reality level of their contributions.

1.4 Overview of the contents of this thesis

Following the introduction presented in this Chapter, Chapter 2 focuses on a further exploration of the project context for the research project on which this thesis is based. It successively addresses the backgrounds and importance of the product category consumer electronics, the disposal of this and other types of waste in the Netherlands in the course of time, the provisions and regulations that have been introduced in recent years by the Dutch government to provide a ‘leak proof’ disposal system for consumer electronics, and especially, the (economic and environmental) results in practice of these provisions and regulations. Chapter 2 clearly demonstrates a major weakness of the current disposal structure for consumer electronics in the Netherlands, the faltering collection of ‘small’ appliances.

Chapter 3 deals with the set-up of the research project on which this thesis is based and explains why and how the original scope and research method have been adjusted. It is explained why and how the research efforts, in the course of time, have been focussed specifically on the collection stage of the Product Recovery Network for consumer electronics in the Netherlands, more particularly with respect to ‘small’ appliances. Finally, Chapter 3 demonstrates that this adjusted scope of the research project requires the execution of a design effort, dedicated to the development of collection rate enhancing measures. This Chapter is concluded with a bird’s-eye view of this thesis, showing how this design process has been integrated into the adjusted research plan, and a further (scientific) characterisation of the (relevance of this) thesis.

Chapters 4 and 5 conclude the first stage of the design process presented in this thesis; the analysis stage. Chapter 4 comprises an analysis of pilot projects dedicated to the collection of ‘small’ consumer electronics, whereas Chapter 5 deals with the theoretical backgrounds of influencing consumer (disposal) behaviour. The analysis stage is concluded with a re-examination of the current Product Recovery Network for consumer electronics in practice, which explains some of the main reasons for the faltering collection of ‘small’ appliances and establishes some reference points with respect to improving this situation.

Chapter 6 presents the second stage of the design process; the synthesis stage. In this Chapter, the lessons that can be learned from practice and theory, presented in Chapters 1 through 5, are applied to generate design alternatives for collection rate enhancing measures with respect to ‘small’ consumer electronics.

Chapter 7 presents the final stage of the design process; the evaluation stage. In this Chapter, the various design alternatives are evaluated based on an appropriate set of criteria, which includes the economic and environmental consequences of introducing specific measures, as well as the practical feasibility.

Finally, an analysis of the political and societal context (in the Netherlands) for the actual introduction of collection rate enhancing measures in practice (Chapter 8) and the presentation of some final conclusions and recommendations for further research and discussions (Chapter 9) bring the analysis presented in this thesis to a close.

Chapter 2

Recovery of consumer electronics in the Netherlands

2.1 Introduction

In the previous Chapter a general description of the *project context* for the research project that formed the basis for this thesis has been advanced. This Chapter is devoted to a further exploration of this project context by answering the following two questions:

(1) Which concepts for organisation and management can be found in the current Product Recovery Network for consumer electronics (in the Netherlands)?

(2) What are the business economic and environmental consequences of the current Product Recovery Network for consumer electronics (in the Netherlands)?

In order to let the answers to these questions have more meaning and to enable and support some sort of prognosticative statements, this Chapter also includes a discussion on relevant developments and trends in recent years, and intentions and agreements for the future.

Therefore, in the remainder of this Chapter, the following topics are discussed:

- consumer electronics; definitions and numbers,
- the recovery of waste in the Netherlands; historical developments,
- the current Dutch Product Recovery Network for consumer electronics; legal and institutional schemes, and,
- relevant national and international trends and developments; legal and institutional boundaries and intentions, social trends and waste developments.

The discussions on these topics are illustrated and founded with relevant facts and figures with respect to e.g. consumer motivation/behaviour, quantities of specific types of (sold and recovered) consumer electronics, and economic and environmental consequences.

The final Section reflects some conclusions based on the findings presented in this Chapter, and a preliminary analysis of the main weaknesses of the current system.

2.2 Consumer electronics

For any discussion on Product Recovery Networks for consumer electronics to make sense, it is essential to have a clear understanding of the terms “Product Recovery Network” and “consumer electronics.” The first term has been discussed in detail in Chapter 1 of this thesis, and the latter is discussed in this Section.

From the start, the term “consumer electronics” has been included in the objective for the study on which this thesis is based. In fact, this study was one of four subprojects included in a research cluster (IOP-project) entitled “Consumer Electronics.” This cluster was part of the “Heavy Metals Programme,” a research project sponsored by the Dutch Department of Economic Affairs. In practice, discussions within the above-mentioned cluster never addressed a specific definition of this term. The reasons behind the absence of such a discussion are probably twofold: (1) “consumer electronics” is a term that seems rather clear-cut to most people, and, (2) most discussions focussed on specific product types that obviously are a part of the category “consumer electronics” in the minds of all members of the cluster. However, at this point in this thesis it is important to make this term more explicit, in order to establish the appropriateness of possible answers to the two research questions that were advanced in the Introduction to this Chapter.

Defining a term like “consumer electronics” is not as easy as it may appear, as can be illustrated by a paragraph entitled “Definition of electric and electronic products” in the report “Waste from electrical and electronic products” that was published by the Nordic Council of Ministers [1995]. In that paragraph the Encyclopaedia Britannica is quoted to define the term “electronic”: *related to electron devices or to circuits or systems based on electron devices*. Subsequently the same source is employed to define the term “electron device”: *a device in which conduction is principally by electrons moving through a vacuum, gas, or semiconductor*. After that, the authors of this report note that “electronic products, with this definition, is a part of the greater family of electric products” [Nordic Council of Ministers, 1995], and define those as: *products that are dependent on electric currents or electromagnetic fields for their correct function*. In the remainder of this report the terms “electronics” and “electric products” are used as synonyms. In fact, the terms “electronics”, “electric products,” and “electrical products,” following the paragraph devoted to defining them, are increasingly intermingled in the course of discussions presented in the report, without preserving any clear distinction.

Another approach to defining a term like “consumer electronics” is by simply enumerating all products that come under that category. This is the approach currently applied by the majority of European governments that have adopted take-back legislation for “electrical and electronic equipment” (the overall wording employed by the European Union). In general, one could say that take-back legislation is directed towards a specific list of electric products, with consumer electronics forming a substantial part of the overall list. These lists give meaning to the term “electric products,” without specifying the exact distinctions between electrical and electronic, and consumer electronics and non-consumer electronics.

This thesis deals with concepts for organisation and management within the Product Recovery Network for consumer electronics in the Netherlands. Consequently, Dutch legal boundaries form the demarcation for current and future concepts for organisation and management. Therefore, it is sensible to assure that the definition applied in this thesis is consistent with the approach of the Dutch government.

Dutch take-back legislation with respect to “consumer electronics” is part of the so-called “Besluit verwijdering wit- en bruingoed,” which could be translated in English to “Disposal of white and brown goods Decree.” This Decree describes a disposal system for electrical household appliances that has come into effect as of January 1st 1999. The main objective of this system is to ensure that discarded household appliances will be returned to producers

or importers (the contents and implications of this system are discussed in more detail in Section 2.4). The Decree does not employ an explicit definition of the term "wit- en bruingoed." However, in the explanatory memorandum accompanying this Decree the term "wit- en bruingoed" is described as "the set of electrical and electronic household and office appliances, ranging from coffee makers and (steam) irons to computers and dishwashers" [Staatsblad 238, 1998]. Furthermore, it is explained in this memorandum that similar appliances that utilise gas or other fuels will sometimes also be within the province of this directive (e.g. gas stoves). The Decree pertains to "appliances that are destined for use in private households or comparable use in companies, e.g. a small refrigerator used in a corporate canteen" [Staatsblad 238, 1998]. Finally, it is explained that certain products that are frequently used in business dealings, i.e. computer, print and telecommunication appliances, also come under this Decree. Subsequently, a list of all product categories that belong to this Decree is given in a separate enclosure ("Bijlage 1 bij artikel 1" [Staatsblad 238, 1998]):

1. *koel- en vriesapparatuur* ~ cold storage and freezing equipment
2. *verwarmingsapparatuur* ~ heating equipment
3. *warmwaterapparatuur* ~ warm water equipment (e.g. boiler, geyser)
4. *was- en wasdroogapparatuur* ~ washing and drying equipment
5. *apparatuur voor koken, bakken of braden* ~ equipment for cooking, baking or frying
6. *geluidsapparatuur* ~ audio equipment
7. *beeldontvangstapparatuur* ~ image receiving equipment (e.g. TV, VCR, decoder)
8. *computers* ~ computers
9. *papierbedrukkende apparatuur* ~ (paper) printing equipment
10. *telecommunicatie-apparatuur* ~ telecommunications equipment
11. *elektrische en electronische oplaadapparatuur* ~ electrical and electronic chargers
12. *elektrische en electronische keukenapparatuur* ~ electrical and electronic kitchen appliances
13. *elektrisch en electronisch gereedschap* ~ electrical and electronic tools
14. *andere elektrische en electronische huishoudelijke apparatuur* ~ other electrical and electronic domestic appliances

The exact range of products that is covered by this list is explained in more detail in the explanatory memorandum accompanying the Decree [Staatsblad 238, 1998].

With respect to the problem of defining the term "consumer electronics" for this thesis, one could argue that some of the fourteen above-mentioned categories would probably not be part of what most people would call "consumer electronics" in their everyday language. At the same time however, this directive on "wit- en bruingoed" is directed towards "household" appliances (as explained above) and therefore the list of products that is laid down as coming under that category could be considered to form a clear (legal) demarcation of the adjective "consumer." Furthermore, "different persons interpret the term 'electronic products' in different ways" [Nordic Council of Ministers, 1995] and any subdivision of this list in "electrical consumer equipment" and "electronic consumer equipment" would, at the very least, be somewhat arbitrary. Especially since there is no separate Product Recovery Network for consumer electronics in the Netherlands (the topic of this thesis), neither in a legal sense, nor in practice.

As a result, rather than to try and come up with an acceptable 'new' definition of the term "consumer electronics," it seems more sensible to answer the two research questions mentioned in the introduction of this Chapter for all products on the list accompanying the Dutch Disposal of white and brown goods Decree. Therefore, from this point forward, in this thesis the term "consumer electronics" is used as a synonym for "white and brown goods" and "electrical household appliances" coming under that list. Accordingly, the general objective put forward in Section 1.2 of this thesis embraces all products on this list ("Bijlage 1 bij artikel 1" [Staatsblad 238, 1998]).

The importance of an environmentally sound Product Recovery Network for consumer electronics, to ensure proper handling of discarded products, can be easily illustrated by some numbers that indicate the (dense) distribution of these products in Dutch society:

- The following table (Table 2.1) reflects the number of products sold for a few of the product categories of the list of products that come under the Disposal of white and brown goods Decree:

Quantity of white and brown goods sold (number of products)			
	1999	*2000*	*growth (in %)*
Cold storage and freezing equipment	892,000	957,000	7 %
Big white goods (e.g. washing and drying equipment)	1,399,000	1,519,000	8.5 %
TVs	1,071,000	1,211,000	13 %

Table 2.1: Sales of white and brown goods in the Netherlands[1]

- The next table (Table 2.2) represents the number of products sold as reported by FIAR (the association of producers, importers and agents in the area of electronics):

[1] Source: PriceWaterhouseCoopers (2001) *NVMP-systeem is doelmatig, het fonds is echter aan de hoge kant* (report commissioned by the NVMP; Utrecht, the Netherlands: PriceWaterhouseCoopers).

Quantity of "consumer electronics entertainment" sold (number of products)			
	2000	*2001*	*growth (in %)*
Video recorders	723,000	648,000	-10 %
DVD appliances	161,000	421,000	262 %
Camcorders	227,000	217,000	-4 %
Digital cameras	129,000	255,000	98 %
Audio home systems	653,000	549,000	-17 %
Audio system components (e.g. cd player, cassette decks)	210,000	216,000	3 %
Portable audio products	143,000	149,000	4 %
Car electronics[2]	294,000	316,000	7 %

Table 2.2: Sales of consumer electronics entertainment in the Netherlands[3]

- Finally, the last table of this Section (Table 2.3) reflects the development of sales of consumer electronics in the Netherlands (indexed) from 1991 up to 1998:

Quantity of consumer electronics sold (indexed)								
	1991	*1992*	*1993*	*1994*	*1995*	*1996*	*1997*	*1998*
Brown goods	100	100	102	109	116	125	134	
White goods	100	97	94	96	93	94	99	
Small household appliances	100	91	87	96	94	93	96	
Computers	100	103	57	82	133	145	179	164

Table 2.3: Sales of consumer electronics in the Netherlands in the course of time[4]

The numbers displayed above clearly demonstrate the magnitude of the environmental problem regarding discarded consumer electronics. Based on Table 2.3 it can be concluded that the number of products that will be set free by consumers in coming years is not very likely to decline. In fact, predictions for the future, as presented by various independent sources, indicate a steady growth in discarded products. These and other future developments are discussed in more detail in Section 2.5.

[2] Also known as ICE: In Car Entertainment.

[3] Source: GfK Benelux Services B.V./FIAR (2002) *De Nederlandse Markt voor Consumer Electronics Entertainment* (report; the Netherlands: GfK Benelux Marketing Services B.V./FIAR).

[4] Source: CREM (1999) *Resultaten nulmeting WEB 1998* (report commissioned by Ministerie van VROM; Amsterdam, the Netherlands: Consultancy and Research for Environmental Management).

2.3 Waste recovery in the Netherlands; a historical overview

Whereas the (separate) collection and treatment of consumer electronics is of recent date, waste management (in the Netherlands) certainly is not. The distribution of responsibilities and obligations in the present-day Product Recovery Network is not only based on current legal regulations, but, at least in part, also ensues from developments in this area in the course of time.

For that reason, before addressing the current Product Recovery Network for consumer electronics, the next Subsection presents a condensed historical overview of (domestic) waste management practices in the Netherlands. This overview is based on the work by Rik G.M. Pieters, as it is presented in his thesis on attitudes and behaviour in a source-separation program. For a more elaborate and detailed overview and analysis, see [Pieters, 1989].

Subsection 2.3.2 focuses more specifically on consumer electronics. Recent (legal) developments and trends are described and the magnitude of the problem facing Dutch society, when it comes to this product category, is illustrated with some telling facts and figures.

2.3.1 Waste management practices in the Netherlands in the course of time

Municipal waste has formed a problem for cities in the Netherlands (and other countries) for many centuries. Until the 14th century all sorts of waste were simply thrown in the streets or in canals, which caused pollution, stench and unhygienic living conditions. Therefore, in the 14th and 15th century, municipal authorities started to bring various legal provisions into being. In fact, the first 'waste directives' and collection systems originate from those days. From the 15th century onwards, most larger Dutch cities had some sort of waste collection and disposal system, although the actual services were usually performed and paid for by citizens.

In the 16th and 17th century local authorities gradually took responsibility for the collection and disposal of municipal waste, even though the rights to perform services and receive payments were usually let to private persons or organisations. Groningen was the first city to preserve these rights for the municipality (1536) and other cities soon followed their example. Simultaneously, many new provisions, directives, and services were created. In some instances, waste was recognised as a valuable resource and the first forms of reuse (e.g. compost for agricultural purposes) became operative. However, the (unhygienic) situation in Dutch cities did not change dramatically until at least the second half of the 19th century.

In the second half of the 19th and the beginning of the 20th century, many Dutch cities stopped letting the rights for waste collection and disposal and founded municipal waste management services. One of the biggest problems facing the newly appointed managers of these services was the choice for an appropriate disposal system for human excreta and in the course of time the sewage system (as we know it in present days) became the central system. The introduction of these municipal waste management services gradually resulted

in a big improvement in hygienic conditions in Dutch cities, and a slow but distinct start was made with the collection of household waste on a regular basis.

The first waste incineration plant was installed in 1912 in Rotterdam, and Leiden and Amsterdam soon followed that example. In the 40s and 50s of the last century about 15% of household waste was composted, 24% was incinerated and 61% was land filled. Since then, the contribution of incineration has increased considerably, and in 1987 15% of household waste was composted, 39% incinerated and 42% land filled (4% is treated differently). In recent years the portion of household waste that is incinerated has increased even more, due to strict land filling legislation.

Clearly, waste management activities in the Netherlands have changed dramatically in the last few centuries, and even in the last few decades. Two important developments in the last few years with respect to waste management in the Netherlands, in light of the topic of this thesis, are:

- Recovery (reconditioning, remanufacturing and recycling)[5] of household waste in a systematic manner has become an important part of Dutch waste management practice. In order to ensure effective and efficient recovery processes, domestic waste needs to be separated, either at the source (by consumers), or at a specialised separation facility. The laying down and bringing into operation of appropriate waste separation schemes has become one of the most important aspects of present-day waste management policy and practices.
- The majority of municipalities in the Netherlands have transferred responsibility for waste management activities like collection and treatment to private firms. In most Dutch cities and villages, these firms are now responsible for all waste management activities that used to be the responsibility of municipal waste management services.

2.3.2 Consumer electronics as a specific waste category

The amount of waste (in weight) caused by consumer electronics is relatively small compared to some other waste categories. In 1998 Dutch consumers discarded some 134 kiloton of consumer electronics, whereas compostable waste, paper, cardboard and glass amounted to 2800 kiloton [CREM, 1999]. However, the environmental consequences of this specific category are considerably more far-reaching, especially in the situation before the Disposal of white and brown goods Decree came into effect [Staatsblad 238, 1998].

The ways in which discarded consumer electronics in the Netherlands were disposed of in the years before 1999 (the year the above-mentioned directive came into force) can be characterised as extremely diverse [Staatsblad 238, 1998]. For certain product categories, e.g. office appliances, producers and suppliers had installed an environmentally sound disposal system. Cold storage and freezing equipment was usually treated under the auspices of municipalities, or (a substantial fraction) exported. However, a considerable

[5] See [Melissen & De Ron, 1999] for a discussion on “defining recovery options.”

portion of discarded consumer electronics ended up in landfill/incineration facilities. These various ways of acting resulted in a number of negative environmental consequences, e.g.:

- The export of CFC and HCFC containing products to Eastern European and African nations results in substantial emissions of these substances, because most of these countries do not have facilities at their disposal that can extract CFCs and HCFCs from these products (before incineration).
- Consumer electronics, especially 'small' appliances, that end up in waste incineration facilities cause the residue after combustion to be unusable as secondary building material. Some 90 % of the brome and 45 % of the copper contents of these residues stems directly from the consumer electronics fraction within the waste stream entering the facility.
- Inadequate handling of discarded consumers can lead to leakages of bromide containing flame-retardants, a wide range of heavy metals, asbestos and PCB's to the environment, resulting in far-reaching negative consequences with respect to public health.

In an attempt to eliminate these problems, Dutch authorities launched (preliminary) consultations with interested parties (e.g. producer associations and consumer associations) on the topic of appropriate disposal systems for consumer electronics as early as 1992. However, these deliberations collapsed in 1994. In 1995 the Dutch Ministry of VROM (Housing, Spatial Planning and the Environment) invited a number of branch associations to come up with plans for appropriate disposal of their products. Unfortunately, after careful examinations, the authorities concluded that these designs failed to provide sufficient points of departure to install an effective disposal system, especially with respect to consumer appliances. All this resulted in Dutch authorities to conclude that the only adequate way of tackling this problem was by means of legislation, ultimately leading to the Disposal of white and brown goods Decree.

This Decree and the present-day Product Recovery Network, arising from the legislational boundaries and prescripts laid out in this Decree, are discussed in the next Section. However, to enable an accurate analysis and assessment of the current situation, it is important to have a clear understanding of the situation up to the introduction of this new disposal system. This situation is described in the report "Resultaten Nulmeting WEB 1998" [CREM, 1999], initiated by the Ministry of VROM. This Section concludes with some key facts and figures from this report:

- In 1998 the most important final destination of consumer electronics was landfill/incineration. For more than 46 % (61 kiloton) of all discarded consumer electronics this was the final destination. The second most important destination was scrap dealers, who received 13 % (17 kiloton) of the disposed waste. Municipalities received 7 kiloton of separated consumer electronics, and other actors received less than 4 kiloton.
- About 10 % of discarded consumer electronics has an unknown destination. One possible explanation for this 'leakage' is that some portion of these 14 kiloton is exported abroad.
- Table 2.4 reflects the ways in which consumer electronics, that are set free by consumers, are disposed of:

The way consumer electronics are disposed of (in %)						
	cold storage and freezing equipment	*'big' white goods*	*TVs*	*ICT*	*other*	*total*
Delivered to producers/importers	0 %	0 %	3 %	0 %	0 %	0 %
Product reuse	27 %	11 %	35 %	66 %	26 %	21 %
Leakage*	73 %	89 %	63 %	32 %	74 %	79 %

Table 2.4: Avenues of disposal for consumer electronics in the Netherlands (1998)[6]

- In Table 2.4, the term "leakage"(*) represents all ways of disposal that are not in accordance with appropriate ways of disposal as laid out in the Disposal of white and brown goods Decree. These leakages do not necessarily represent environmentally unfriendly operating procedures. A portion of the 79 % leakage of all consumer electronics is dismantled at a so-called "sociale werkplaats" (social services workplace), and some of the components are subsequently remanufactured and the remainder of the materials is recycled. However, within this leakage stream some 89 % of all consumer electronics that are set free by consumers end up at landfill/incineration facilities.
- Especially for some 'smaller' appliances a very common way of disposal is to put the discarded product in the refuse bag/bin. Later in this thesis this widespread way of acting is distinguished as one of the key problems, and certainly one of the most persistent problems, when it comes to changing consumer behaviour in an environmentally acceptable direction. The magnitude of this problem is illustrated in Table 2.5:

Disposal by means of refuse bag/bin	
product category	*quantity in 1998 (number of products)*
Electrical and electronic kitchen appliances	539,239
Other electrical and electronic domestic appliances	517,670
Telecommunications equipment	179,746
Electrical and electronic tools	57,519

Table 2.5: Ways of disposal of 'small' consumer electronics[7]

- One important conclusion that could be drawn from the consumer survey [ITM Research, 1999] that was carried out as part of the "Nulmeting WEB 1998" [CREM, 1999], is that the following peculiar set of two argumentations guides consumers in their decisions with respect to ways of disposing of 'small' appliances:

[6] Source: CREM (1999) *Resultaten nulmeting WEB 1998* (report commissioned by Ministerie van VROM; Amsterdam, the Netherlands: Consultancy and Research for Environmental Management).

[7] Source: ITM Research/CREM/VROM (1999) *Consumentenenquete WEB-monitoring* (report project Q107; Amsterdam, the Netherlands: ITM Research).

1. Personal benefits from ‘appropriate’ ways of disposal are considered to be relatively small.
2. Damages caused by ‘inappropriate’ ways of disposal are considered to be relatively small.

As a result, consumers are not willing to invest a lot of effort in alternative ways of disposal. The problem arising from this typical ‘mindset’ of consumers, especially regarding ‘small’ appliances, emerges at several points in the analysis presented in this thesis and is discussed in more detail in Chapter 5, as it represents one of the central barriers blocking the success of the current Product Recovery Network for consumer electronics in the Netherlands.

2.4 The present-day Product Recovery Network for consumer electronics

This Section deals with the current Product Recovery Network for consumer electronics in the Netherlands. The next Subsection addresses the objectives of the Disposal of white and brown goods Decree and the legal restrictions and regulations stemming from that Decree. Subsequently, Subsection 2.4.2 outlines the actual consequences for consumers, municipalities and producers and importers, and the way a disposal structure for consumer electronics has been effectuated in practice. Following this discussion, Subsection 2.4.3 presents an overview of the environmental and (business) economic consequences of this new structure and compares these consequences with the objectives of the Decree and the situation before the Decree came into effect (as described in the previous Section). Some preliminary observations and conclusions with respect to the strengths and weaknesses of the current Product Recovery Network for consumer electronics in the Netherlands are advanced and are discussed in more detail in Section 2.6.

2.4.1 The Disposal of white and brown goods Decree

June 1st 1998 the Disposal of white and brown goods Decree came into force. In practice, this meant that the disposal structure for ‘big’ consumer electronics had to be effectuated as of January 1st 1999 and the disposal structure for ‘small’ appliances as of January 1st 2000.

The general objective of this Decree was to enforce a leak proof disposal structure for consumer electronics, which results in the reuse of as many products and materials as possible and disposal of the wastes in such a way that the associated risks to the environment are minimised. The Decree advocates a fair distribution of tasks and responsibilities among consumers, suppliers, repair companies, local authorities, and producers and importers, in order to encourage prevention (ecodesign) and reuse and to ensure that disposal takes place in a cost-effective manner.

The mainspring for calling this Decree into being were the environmental problems caused by inappropriate handling of discarded consumer electronics, as discussed in Subsection 2.3.2 of this thesis. In the explanatory memorandum accompanying the Decree it is explained that the greatest environmental benefit of this Decree is formed by “the countering of the dispersion of CFCs, the dispersion (and squandering) of bromide, arsenic,

copper, chromium, mercury and lead from large white and brown goods, the dispersion of nickel and cadmium from built-in batteries, PCBs from the condensers of white and brown goods and asbestos from heat-resistant equipment and appliances" [Staatsblad 238, 1998].

With respect to CFCs and HCFCs the Decree imposes a total ban on having refrigerators and freezers containing CFCs and HCFCs in stock for commercial purposes. The following trains of thought are presented in the explanatory memorandum accompanying the Decree as the background to this ban [Staatsblad 238, 1998]: "Each year around 450,000 refrigerators and freezers are discarded in the Netherlands. From these about 180 ton of CFCs and HCFCs (from a total annual emission in the Netherlands of 1,150 ton of CFCs and HCFCs) can be recovered. Until 1995 CFCs and HCFCs were used as the refrigerant (about 30%) in refrigerators and freezers and as the foaming agent in the manufacture of insulating foam (about 70%). Approximately 30% of the discarded refrigerators and freezers (120,000) are exported, mainly to Africa. They are exported in particular to countries that do not have an adequate system for processing the CFCs and HCFCs. The resulting emissions of gases that deplete the ozone layer are substantial (about 60 ton each year). Imposing a ban on having second-hand refrigerators and freezers containing CFCs and HCFCs in stock for commercial purposes seals this unwanted leak in the disposal scheme. It can also be stated that the recovery of CFCs and HCFCs from refrigerators is a highly cost-effective means of reducing the greenhouse effect (Dfl. 8 {~3.63 Euro} per ton of CO2 equivalent avoided; in the case of energy savings this is about Dfl. 35 {~15.91 Euro} per ton of CO2 equivalent)."

Countering the unwanted dispersion of CFCs and HCFCs (from cold storage and freezing equipment) is only one of the objectives of installing the Disposal of white and brown goods Decree. A considerable portion of environmental problems that are associated with inappropriate handling of discarded consumer electronics concern 'small' appliances. A number of these appliances contain heavy metals that constitute a substantial health risk if they end up in the environment. Separate collection and environmentally sound treatment of these products should eliminate this risk and this forms another important environmental benefit aimed at by installing the Decree. A further benefit is illustrated in the explanatory memorandum to the Decree as follows [Staatsblad 238, 1998]: "The Netherlands Organisation for Applied Scientific Research (TNO) has calculated the effects of the separate collection of small white and brown goods, including appliances that have a screen, on the quality of MSWI bottom ash and fly ash (Model-type analysis of total incineration of small-scale chemical waste and small white and brown goods; MEP-R96/414, Nov. 96). These white and brown goods contain a relatively high quantity of bromide, copper, tin, nickel and lead compared with "standard household waste". The removal of tin (100%) from these white and brown goods is expected to have big impacts. Furthermore, the bromide content in bottom ash and fly ash can be reduced by 90% and the copper content by 40% to 50%. As a result, MSWI bottom ash may no longer fall into the outdoor category of the Building Materials (Soil and Surface Waters Protection) Decree (Bouwstoffenbesluit bodem- en oppervlakte-waterbescherming), so that additional environmental precautions for their use will no longer be necessary and sales in the long term are assured. In 1995, 700 kiloton of MSWI bottom ash was released. In the next few years this figure will rise to 1.2 million ton a year. The above research took into account the total withdrawal of small white and brown goods from the input of incinerators. In practice, this percentage will be lower of course. It can be concluded that removing this waste from household waste will have a big impact on improving the quality of incinerator residues,

which is one of the pillars of the 1995 Incinerator Residues Implementation Plan (Implementatieplan AV-reststoffen 1995)."

The Disposal of white and brown goods Decree formulates a number of restrictions and regulations to ensure that these objectives will be attained. Some key elements in this Decree are listed (in an adapted form, to enhance comprehensibility for the reader) in Table 2.6:

Key elements of the Disposal of white and brown goods Decree
→It is prohibited to incinerate consumer electronics that have been collected or taken back separately in regular (household) waste incineration facilities.
→It is prohibited to have in stock for commercial purposes (CFC and/or HCFC containing) refrigerators and freezers discarded after use. These refrigerators and freezers shall be processed in an environmentally sound manner. Our Minister will lay down specific rules relating to the method of processing.
→When supplying a new product, suppliers shall take back as a minimum free of charge a similar product that has been discarded after use and that is tendered to them.
→Local authorities shall provide for: separate collection of the products originating from private households and belonging to that category; the creation and maintenance of a place (municipal storage facility) within the municipality or within the municipalities with which they are working together where a supplier can leave a product taken back from a private household and belonging to that category.
→Manufacturers and importers shall ensure that a product of the brand that they have put or are putting on the market in the Netherlands is taken back and further disposed of if it is tendered to them by a repair company or by the local authority.
→Manufacturers and importers shall ensure that if, when providing a supplier with a new product, a similar product is tendered to them, this product is taken back and further disposed of.
→Products that have been discarded by private households and have been collected by the local authority shall be taken back from the municipal storage facility.
→Manufacturers or importers shall finance the cycle deficit (the negative balance that occurs when the cost of disposing of a product is higher than the revenue from that disposal) from the supplier, the repair company and from the municipal storage facility.
→Manufacturers and importers shall give Our Minister notification of the manner in which they will perform these duties. This notification shall as a minimum state: the way in which products will be taken back from the supplier, the repair company or the local authority; what percentage of the products taken back will be reused; what percentage of the remaining products taken back, or components thereof, will be disposed of in a different manner; how the disposal scheme will be financed; the measures that will be taken to ensure that products are taken back and further disposed of if the manufacturer or importer ceases to market products in the Netherlands; monitoring of the subjects mentioned above.
→This notification shall require the approval of Our Minister.
→Manufacturers or importers may give joint notification and form an organisation of manufacturers or importers who perform these duties on their behalf.

Table 2.6: Summary of the Disposal of white and brown goods Decree

For interested readers, the full version of the Disposal of white and brown goods Decree is appended to this thesis as Appendix I. However, within the framework of the analysis

presented in this thesis it is more important to understand the meaning and consequences of this Decree in practice. The latter is the topic of the next Subsection.

2.4.2 The resulting Product Recovery Network in practice

With respect to the effectuation in practice of the Disposal of white and brown goods Decree, the last point in Table 2.6 indicates that manufacturers and importers in the Netherlands were allowed to give joint notification and form an organisation to perform the duties, assigned to them in the Decree, on their behalf. After the Decree came into effect manufacturers and importers have indeed established two collective disposal structures, based on a joint notification that was approved by the Minister (the responsible authority within the Dutch government). In practice, this means that the Product Recovery Network for consumer electronics in the Netherlands is composed of two separate take back systems:

1. A system for ICT (Information and Communication Technology) equipment, also referred to as 'grey' goods. This system focuses on categories 8, 9 and 10 of the list of all product categories [Staatsblad 238, 1998] that come under the Disposal of white and brown goods Decree (also see Section 2.2 and Appendix I of this thesis). Products that are addressed by means of this system are e.g. computers, printers, fax machines, photocopiers and telephones. This system was set up and has been managed by ICT Milieu (ICT Environment), an organisation set up by manufacturers and importers in the ICT sector.
2. A system for all other product categories coming under the Decree. Products that are addressed by means of this system range from refrigerators and washing machines to television sets, electric shavers and coffee makers. This system was set up and has been managed by the NVMP (Netherlands association for Disposal of "Metalectro" Products), an organisation set up by manufacturers and importers in the electric products sector.

These two take back systems, the ICT system and the NVMP system, differ from each other on two specific points:

1. In the NVMP system retailers are supposed to hand over discarded products, that have been handed in to them by consumers, to the local waste disposal authority, a Regional Storage Station (RSS; a joint facility of co-operating municipalities), or the distribution centre of the company chain it belongs to. It is possible to hand over the discarded products to the NVMP transport service, however, this system is only intended for those retailers that are not able to make use of one of the above options [NVMP, 2002]. In the ICT system, the retailer may resell the equipment he has taken back, hand over the discarded products to the local waste disposal authority, a Regional Storage Station, a (chain) distribution centre, or have the products taken back by the carriers participating in the ICT take back system, free of charge [ICT Milieu, 2002]. In other words, the NVMP transport service is only intended to visit individual retailers as an exception, in the ICT system visits to individual retailers by the participating carriers is deemed to be a regular service.
2. In the NVMP system the costs of the disposal structure are financed through funds raised by means of a disposal levy (the so-called "Verwijderingsbijdrage"),

charged to consumers whenever they buy a product that comes under the Disposal of white and brown goods Decree [NVMP, 2002]. Manufacturers and importers participating in the ICT system bear the costs of transporting and treating the ICT equipment they take back themselves. Payment is made (in arrears) after the equipment has been processed at a specialised processing facility (recycling company). In other words, while the NVMP system is financed by a 'visible fee' at the moment of sale, the ICT system has no 'visible fee' and producers and importers receive an invoice at regular intervals for transport and treatment of (their branded) products that have in fact been collected and processed (plus an additional charge for 'orphaned/free riders' products).

Despite these two differences, the general ramifications of the two take back systems that are operational in the Netherlands are very similar. In fact, both systems can be depicted schematically as follows (Figure 2.1):

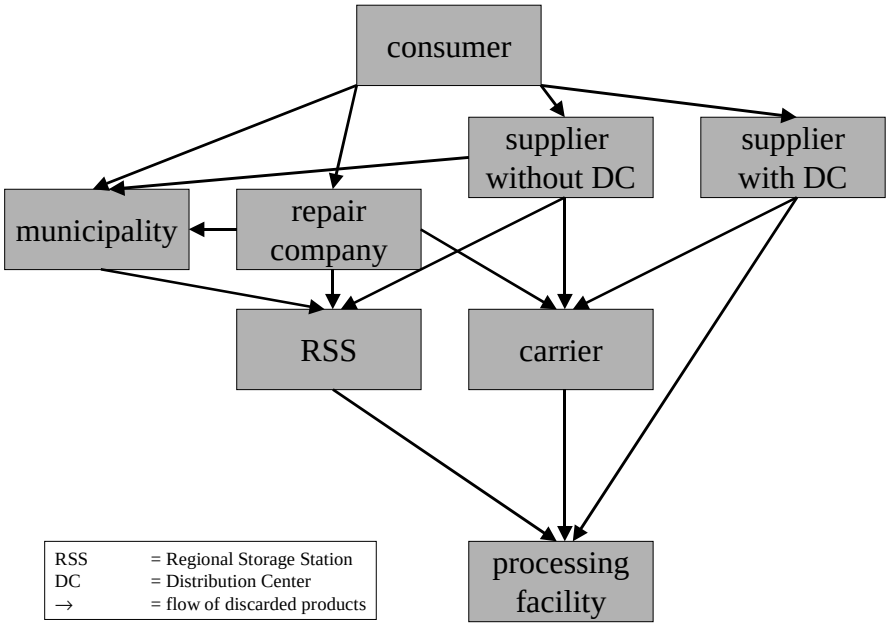


Figure 2.1: General disposal structure for consumer electronics in the Netherlands

Subsequently, the general consequences of the current Product Recovery Network for consumer electronics in the Netherlands for each of the parties involved, can be reflected as follows:

Consequences for consumers

- Consumers have to pay a disposal levy ("Verwijderingsbijdrage") whenever they buy a product that comes under the Disposal of white and brown goods Decree, with the exception of ICT equipment (categories 8, 9 and 10 of the list of all product categories [Staatsblad 238, 1998] that come under the Decree).
- They can dispose of their used consumer electronics in two ways:
  1. When purchasing a similar new product, they can hand over the old product to the retailer or supplier (the 'selling' party) free of charge.
  2. They can hand over their old product to the local waste authority. The method of 'collection' varies from one municipality to another. Some municipalities see to it that discarded products, that have been deposited at the street (curbside), are collected and transported, but the vast majority only offers a so-called 'bring facility' (e.g. a municipal waste yard), where consumers can hand in their used products. Some municipalities even charge their townsmen for these services.

Consequences for suppliers

- Dealers, retailers, distributors, and so on, are required to take back used products handed over to them by consumers that buy a similar new product, free of charge.
- They can dispose of these collected consumer electronics in a number of ways:
  1. They can resell the used products (with the exception of CFC and HCFC containing products [Staatsblad 238, 1998]).
  2. They can have the products collected and transported by carriers participating in the NVMP system/ICT system.
  3. They can send them to the distribution centre of the company chain they belong to, where the discarded products will be collected by carriers participating in the NVMP/ICT system.
  4. They can arrange for handing over the used products to the municipality in a similar way as consumers.

Consequences for repair companies

- They can dispose of used products in a similar way as suppliers.

Consequences producers and importers

- Producers and importers that are associated with the NVMP system have to transfer the disposal levy for each product put on the market in the Netherlands to the NVMP.
- Producers and importers that are associated with the ICT system have to pay the invoices from participating processing companies and carriers.

Consequences for municipalities

- To the extent that consumer electronics constitute a part of bulky or other household waste local authorities already have a duty to collect these.
- Local authorities are required to likewise provide for the separate collection of 'small' consumer electronics from consumers, repair companies and suppliers[8]. Separate collection is seen not so much as a distinct collection system for these products, but collection "in such a way that the collected products can be transferred easily to the manufacturers or importers" [Staatsblad 238, 1998]. This collection duty can be carried out in two ways:
  1. The introduction of a 'bring facility' (e.g. municipal waste yard), where consumers, repair companies and suppliers can hand in used products.
  2. A curbside collection system.
- Like the supplier, the local authority may resell the collected products (with the exception of refrigerators and freezers containing CFCs and HCFCs) or, if this is impossible or if the local authority does not wish to do so, these products can be handed over to the manufacturers or importers (represented by the NVMP and ICT Milieu).
- Municipalities are allowed and encouraged to participate in the realisation of Regional Storage Stations (RSS). A RSS serves as a link (by means of storage and sorting) between municipalities and producers and importers and facilitates a smooth transfer of discarded products. Usually, several co-operating municipalities participate in one RSS. Most municipalities in the Netherlands are linked to a RSS.

From the consequences listed above some very important issues regarding the current Product Recovery Network in practice emerge.

First of all, it is clear that municipalities in the Netherlands (individually and/or co-operating in a Regional Storage Station) play a pivotal role in the current disposal structure, which is illustrated in Figure 2.2. They act as the linking pin between consumers, retailers and repair companies on one side, and producers and importers, represented by the NVMP and ICT Milieu, on the other.

[8] It is important to note that municipalities are only required to accept white and brown goods originating for use by private households. Even though the Disposal of white and brown goods Decree also refers to specific product categories that originate from comparable use in companies, municipalities are not required to collect these products. These companies are not allowed to hand over these products to the local waste authority and are required to ensure proper handling themselves [Informatiecentrum Preventie en Hergebruik, 1998].

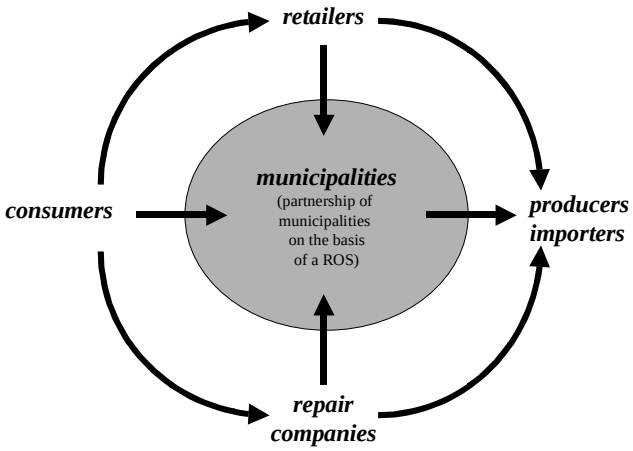


Figure 2.2: The pivotal role of municipalities in collecting consumer electronics

Municipalities are responsible for the (separate) collection of products coming under the Disposal of white and brown goods Decree that are set free by consumers, retailers and repair companies. However, municipalities are not responsible for collecting products set free by companies that use them in a comparable way (even though these products come under the same Decree) and they are not required to enhance collection rates. The latter forms a very important observation with respect to the main weaknesses of the current Product Recovery Network (also see Section 2.6).

Officially, consumers can dispose of their used products in two ways: hand them over to suppliers, when buying a similar new product, or hand them over to local waste authorities. In practice, Subsection 2.3.2 shows that consumers used to dispose of (before 1999) a lot of their products by means of the refuse bag/bin. In the current Product Recovery Network this environmentally unfriendly way of acting may not be an 'official' option available to consumers, but there is nothing in the current set-up of the system to prevent this behaviour. What's more, the current system incorporates no specific rewards and/or penalties to change this. Environmentally friendly ways of acting require the consumer to invest effort and sometimes even money, because most municipalities do not offer curbside collection services and some even charge a fee for handing in used products at their municipal waste yard. Environmentally unfriendly ways of acting, such as disposing of used consumer electronics by means of the refuse bag/bin, have no immediate negative consequences for the individual consumer other than a possible 'sense of guilt.' This topic is discussed in more detail in Section 2.6 and Chapters 5 and 6 of this thesis.

With respect to producers and importers it is obvious that their involvement with the current Product Recovery Network is rather indirect. Their duties by virtue of the Disposal of white and brown goods Decree are performed on their behalf by the NVMP and ICT Milieu. Their interference with the collection and processing of used products is limited to fulfilling financial obligations: either handing over the disposal levy for products put on the

market (for companies coming under the NVMP system), or paying invoices for the processing of collected products (for companies coming under the ICT system).

The responsibilities of the NVMP and ICT Milieu are very clear. They are responsible for taking in all consumer electronics handed over to them by consumers, suppliers, repair companies and municipalities, and the environmentally sound (as prescribed by law) processing of these products. The execution of these tasks is funded by the money coming in from the disposal levy (NVMP) and the invoices send to participating companies (ICT). It is very important to note that the NVMP and ICT Milieu are not responsible for the appropriate collection of discarded consumer electronics and are certainly not required (by law) to enhance collection rates. In fact, it could be argued that enhanced collection rates would only increase their workload and working expenses, ultimately leading to higher financial burdens for the companies they represent.

2.4.3 The results of the current Product Recovery Network as yet

This Subsection attempts to present an overview of the environmental (based on collection rates and reuse percentages) and (business) economic consequences of the introduction of the Product Recovery Network for consumer electronics in the Netherlands, as described in the previous Subsection. However, achieving this objective poses a serious challenge to say the least, seeing that reliable data in this field are very scarce and scattered. The overview in this Subsection is based on available data from a number of different sources. In some instances, the facts and figures brought forward can vary quite significantly (also in preciseness) from one source to another. The following overview does not attempt to pass judgement on the reliability of various sources or the scientific foundation of specific findings. Instead, it presents a general analysis and, if possible, draws some important general conclusions with respect to the impact of the current Product Recovery Network in practice.

In a report issued by PriceWaterhouseCoopers [1999], commissioned by the NVMP, the following table (Table 2.7) was included:

Collection "response" white and brown goods (in %)				
Product category	*1999*	*2000*	*2001*	*2002*
Cold storage and freezing equipment	70	80	90	100
'Big' white goods	70	80	90	90
'Small' white goods	40	50	60	60
'Small' household appliances	0	30	35	40
TVs	70	80	90	90
Other image receiving equipment	40	50	60	60
Other brown goods	0	30	40	50

Table 2.7: Assumptions on collection "response" for NVMP calculation model[9]

This table represents a number of assumptions, with respect to collection rates of consumer electronics, adopted in a calculation model applied by PriceWaterhouseCoopers to assess the impact of the disposal structure as it was set up by the NVMP. Without getting into a debate about the exact meaning of the term "collection response," this table reveals that the NVMP already made allowance (in 1999) for the fact that their disposal structure would probably favour 'bigger' appliances to 'smaller' appliances. Table 2.7 shows that assumptions regarding "collection response" for 'small' consumer electronics, such as 'small' white goods and 'small' household appliances, amount to significantly lower percentages than for relatively 'big' equipment, such as cold storage and freezing equipment and TVs.

This first impression of some sort of selective adequacy of the NVMP system when it comes to specific product categories coming under the Disposal of white and brown goods Decree was confirmed in a first report on actual collected quantities [PriceWaterhouseCoopers, 2001]. This report included the following table (Table 2.8) on collection rates of three specific product categories:

[9] Source: PriceWaterhouseCoopers (1999) *Collectief systeem voordelig voor individuele producenten/importeurs en milieu* (report commissioned by the NVMP; Utrecht, the Netherlands: PriceWaterhouseCoopers).

Quantity of collected white and brown goods (numbers *1000)									
	cold storage and freezing equipment			*'big' white goods*			*TVs*		
	1999	*2000*	*growth*	*1999*	*2000*	*growth*	*1999*	*2000*	*growth*
Actual	459	572	24.6 %	147	285	93.9 %	171	309	80.7%
Estimated/ expected	430	430	-	638	769	20.5 %	304	304	-
Percentage (in %)	106	133	-	23	37	-	56	102	-

Table 2.8: Collected quantity of specific categories of consumer electronics[10]

The figures in this table clearly show that the NVMP system is functioning properly with respect to collection rates of 'big' consumer electronics, such as cold storage and freezing equipment and TVs. The collection rates for 'big' white goods are remarkably low, but PriceWaterhouseCoopers [2001] explains this by referring to the high positive value of recyclable materials in these products, leading to a relatively large portion of discarded products being sold in the recycling branch. This problem is discussed in more detail (including possible solutions) in [De Koster et al, 2002].

In the same report [PriceWaterhouseCoopers, 2001], the collection rate for "other consumer electronics" coming under the NVMP system, mainly 'small' appliances, such as 'small' white goods, 'small' household appliances and other brown goods, is reported to be as low as 53,7 % of the estimated amount of products that should have been collected in 2000.

The actual amount of collected "other consumer electronics" is 6.4 kiloton in 2000 [PriceWaterhouseCoopers, 2001] and 10 kiloton in 2001 [NVMP, 2002]. Comparing these numbers to the expected amount of discarded "other consumer electronics" [CREM, 1998], instead of the expected amount entering the NVMP system, results in even more telling percentages. This is represented in Table 2.9:

[10] Source: PriceWaterhouseCoopers (2001) *NVMP-systeem is doelmatig, het fonds is echter aan de hoge kant* (report commissioned by the NVMP; Utrecht, the Netherlands: PriceWaterhouseCoopers).

Collection rates of "other consumer electronics"			
	actually collected by means of the NVMP system (kiloton)	*estimated amount discarded by consumers (kiloton)*[11]	*actual collection rate NVMP-system*
2000	6.4	24.4	~ 26 %
2001	10.0	26.6	~ 37 %

Table 2.9: Actual collection rates "other consumer electronics" for the NVMP-system

From all the above, the general conclusion with respect to the NVMP system, including the actual collection by municipalities, retailers and repair companies, is that the separate collection of consumer electronics, as prescribed in the Disposal of white and brown goods Decree, appears to be realised better for 'big' appliances than for 'small' appliances.

With respect to ICT equipment, categories 8, 9, and 10 of the list of all product categories [Staatsblad 238, 1998] that come under the Disposal of white and brown goods Decree, a similar impression emerges. Table 2.10, with numbers provided by Marian Oppelaars of ICT Milieu, represents the actual processed amount of ICT equipment in the years 1999, 2000, and 2001:

Processed ICT equipment in kg						
	cat. 8	*cat. 9*	*cat. 10*	*orphaned*	*accessories*	*total*
1999	1,068,932	299,641	7,767	1,273,123	129,153	2,778,616
2000	2,720,925	912,908	23,852	2,860,719	286,714	6,805,118
2001	3,839,236	1,297,148	41,126	3,011,564	349,473	8,538,547

Table 2.10: Total amount of ICT equipment processed by ICT Milieu

The total amount of ICT equipment that was processed, and therefore at least the amount that was collected, has increased considerably in those three years. If the amount processed in 1999 is compared to the estimated amount that was discarded in that year [CREM, 1999], the resulting collection rate for all ICT equipment is at least somewhere in the range of (2,778,616/12.400.000=) 22 %. The same comparison for the years 2000 and 2001 results in collection rates of at least 55 % and 58 % respectively.

For products in category 10, relatively 'small' appliances such as telephones and answering machines, a similar comparison results in significantly lower percentages. Based on [CREM, 1999], the average weight of products in this category can be estimated to be close to 1 kilogram, which means that the weights in kilograms presented in Table 2.10 correspond closely to the total amount of collected 'small' ICT equipment in numbers. In Table 2.11 these numbers are compared with the amount of discarded telecommunications equipment (category 10) in 1998 [CREM, 1999]. The latter could serve as an extremely conservative estimate of the amount of discarded telecommunications equipment in the

[11] Source: CREM (1999) *Resultaten nulmeting WEB 1998* (report commissioned by Ministerie van VROM; Amsterdam, the Netherlands: Consultancy and Research for Environmental Management).

years 1999, 2000 and 2001, since the overall trend for ICT equipment is that the amount of discarded products increases with 24.3 % a year [CREM, 1999].

Comparing collected amount with a conservative estimation of discarded amount			
	actually collected by means of the ICT-system (kg)	*conservative estimate of amount discarded by consumers (kg)*	*estimated collection rate ICT-system*
1999	7,767	488,910	~ 1.5 %
2000	23,852	488,910	~ 4.8 %
2001	41,126	488,910	~ 8.4 %

Table 2.11: Conservative estimate of collection rates for product category 10

All the above shows that collection rates for ICT equipment as a whole are relatively low (in the range of 50-60 %), when compared to cold storage and freezing equipment and TVs. An obvious explanation for this fact ensues from the observation that discarded ICT equipment is in high demand on second-hand markets and is being sold by the piece to other consumers. However, Table 2.11 clearly shows that the collection rates for 'small' appliances in the ICT sector, telecommunications equipment, are extremely low, even if collected amounts are compared with a very conservative estimate for the amount of discarded products. Therefore, the general conclusion with respect to the ICT system, including the actual collection by municipalities, retailers and repair companies, is that the collection of consumer electronics, as prescribed in the Disposal of white and brown goods Decree, appears to be realised better for 'big' appliances than for 'small' appliances.

As far as the way consumer electronics are collected is concerned, consumers only scarcely make use of the option to hand in their 'old' products when buying a 'new' one [Veerman, 2002]. The NVMP collects about 80 % of the products handed over to them at Regional Storage Systems and about 20 % at retailers (or Distribution Centres). ICT Milieu collects only a very small amount of ICT equipment at retailers and Distribution Centres [Veerman, 2002].

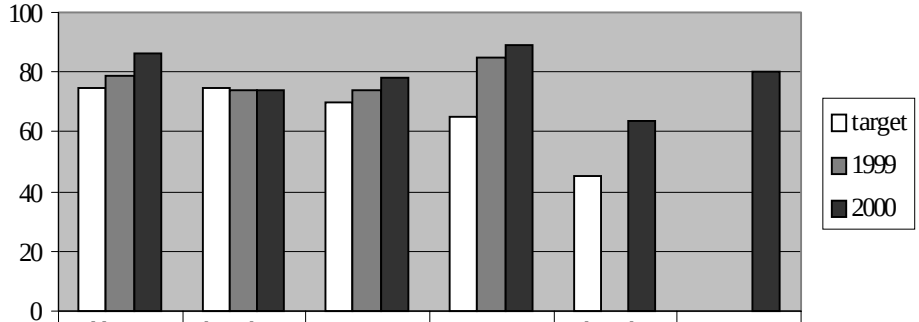
At present, there are some 63 Regional Storage Stations in the Netherlands serving all 500 municipalities. The Regional Storage Stations receive a financial contribution from the NVMP and ICT companies for transporting collected products from municipalities to the RSS and sorting [Veerman, 2002].

From these Regional Storage Stations the discarded products are transported by carriers participating in the NVMP and ICT systems to one of 5 processing companies [Veerman, 2002]. Two of these companies specialise in processing TVs, one in cold storage and freezing equipment. 'Small' consumer electronics are processed at two different companies and one company handles all 'big' white goods.

With respect to the actual processing of the collected consumer electronics reliable data are extremely scarce and varied. This incomplete picture stems from the fact that the Disposal of white and brown goods Decree does not prescribe how these processing companies (or the NVMP/ICT Milieu) should report on these activities. However, the Decree does require the NVMP and ICT Milieu to indicate the resulting reuse percentages of the processing step in their disposal systems. In the explanatory memorandum accompanying the Decree, reuse

is defined as follows: "All the actions covered by one of the actions for the recovery of wastes as referred to in Appendix II B of Directive 75/442/EEC of the Council of the European Communities of 15 July 1975 regarding wastes, most recently amended by Directive 91/156/EEC. These actions include actions directed at the reuse of products, components, materials, and the use principally as a fuel or other means to generate energy. Manufacturers and importers must indicate what percentage of the returned products will be reused. They are in principle free to choose the form of reuse: the reuse of products, components, materials or the use principally as a fuel" [Staatsblad 238, 1998].

In practice, the average reuse percentage for all collected consumer electronics is about 80 %. Figure 2.3 indicates the reuse percentages for specific product categories[12]:



	cold storage and freezing	big' white goods	TV	ICT	other white and brown	total
target	75	75	70	65	45	
1999	79	74	74	85		
2000	86	74	78	89	64	80

Figure 2.3: Targeted and achieved reuse percentages for specific product categories[13]

Two important conclusions that can be drawn from the above are:

1. The NVMP and ICT Milieu have achieved the objectives with respect to the environmentally sound processing of consumer electronics, as they have been included in their notification to the Minister. As such, they have fulfilled the requirements laid down in the Disposal of white and brown goods Decree.
2. As with collection, the reuse percentage for 'small' consumer electronics coming under the NVMP system is significantly lower than the reuse percentage for other product categories.

[12] Cold storage and freezing form a 'special' product category because they contain CFC and HCFC. The collection rates for this product category are relatively high (also see Table 2.8) and this is a direct result of the ban on commercial trading of these products. The processing of these products is subject to strict legal boundaries and executed by a specialised recycling company (Coolrec B.V.).

[13] Source: Veerman, K. (2002) *Drie jaar ervaring met het afvalbeheer van wit- en bruingoed* (report; Den Haag, the Netherlands: Kees Veerman, VROM).

Finally, with regard to the (business) economic/financial consequences of the current Product Recovery Network, the following observations apply:

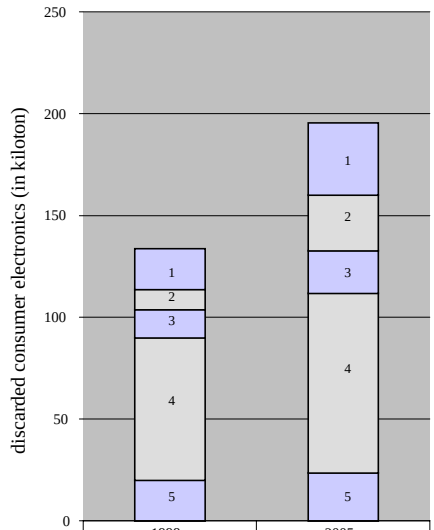
- Consumers have to pay a disposal levy when buying a product that comes under the NVMP system. In some cases, they also have to pay a fee for curbside collection of consumer electronics, or for handing in their used products at the municipal waste yard.
- Retailers have to comply with the obligation to take in used products from consumers. Therefore, they are confronted with additional personnel and storage costs. In fact, handing these products over to local waste authorities usually results in additional costs, since most municipalities charge a fee for collecting/taking in discarded products.
- Municipalities are co-operating by means of Regional Storage Stations. This way of organising the handing over of collected consumer electronics to the NVMP and ICT Milieu results in considerable savings, e.g. shared overhead costs, less storage space needed at municipal waste yards. At the same time, municipalities co-operating in a RSS receive fees from retailers and repair companies for collecting and taking in discarded products and financial contributions from the NVMP and ICT companies for transporting the products to the RSS and sorting.
- The only financial burden for companies that participate in the NVMP system consists of handing over the disposal levy they receive from customers to the NVMP. At present, the NVMP indicates that the funds raised by the disposal levy have become "higher than intended and necessary" [PriceWaterhouseCoopers, 2001].
- The only financial burden for companies that participate in the ICT system consists of paying the invoices send to them by ICT Milieu. These invoices are mostly directly related to the costs charged by the carriers and processing companies participating in this system. ICT companies are entitled to adapt the selling prices of their products if they feel this is necessary to be able to bear these costs [ICT Milieu, 2002]. Whether or not they have indeed effectuated this right is unclear at this point.

Initially, the overall conclusion from the above observations can only be that consumers and retailers are confronted with additional costs as a consequence of the Disposal of white and brown goods Decree coming into effect, whereas municipalities and producers/importers have the opportunity to call additional ways of financing into being. The latter implies that the negative (business) economic consequences for these parties are relatively low or even non-existent.

2.5 Relevant trends and developments

Before drawing any final conclusions with respect to the current Product Recovery Network for consumer electronics in the Netherlands (Section 2.6), it is important to address legal, societal and waste developments that could influence the (future) functioning of this disposal structure. This Section conveys some notable trends in these three areas.

First of all, the amount of discarded consumer electronics that needs to be handled by the (future) arsenal of disposal structures will increase considerably. By the year 2005 the total amount of discarded consumer electronics coming under the Disposal of white and brown goods Decree will be somewhere in the region of 196 kiloton [CREM, 1999]. This forecast is based on the purchase and disposal figures in the past, resulting in an annual increase of the total flow of discarded consumer electronics of 6-7 % from 1998 to 2005. These 196 kiloton should be considered a maximum (no considerable increase should be expected after 2005), based on the fact that available data "do not show an increase in the amount of sold white and brown goods" [CREM, 1999]. The magnitude of the increase in the total flow of discarded consumer electronics and the contribution of specific product categories are illustrated in Figure 2.4:



	1998	2005
1) other white and brown goods	20	35
2) ICT	10	27
3) TV	14	21
4) big white goods	70	88
5) cold storage and freezing equipment	20	24

Figure 2.4: Amount of discarded consumer electronics in 1998 and 2005 (kiloton)[14]

Another important development deals with specific societal trends that could have a negative impact on the functioning of a disposal structure for consumer electronics. As was indicated in Subsection 2.4.2, the current Product Recovery Network hinges largely on a sense of joint responsibility of consumers. The current system incorporates no specific

[14] Source: CREM (1999) *Resultaten nulmeting WEB 1998* (report commissioned by Ministerie van VROM; Amsterdam, the Netherlands: Consultancy and Research for Environmental Management).

rewards and/or penalties to change environmentally unfriendly ways of acting. Simultaneously, environmentally friendly ways of acting require the consumer to invest effort and sometimes even money. Therefore, the so-called "internal motivation" [Poiesz, 1999] of consumers to display appropriate disposal behaviour plays a pivotal role with respect to the collection stage of the current Product Recovery Network. In light of this observation, the following two tables (Table 2.12 and Table 2.13) provide a disenchanting perspective:

Perception of major societal problems of people aged 18 and over (in %)									
	1971	*1972*	*1977*	*1981*	*1982*	*1986*	*1989*	*1994*	*1997*
Crime: law and order	8	5	14	13	13	17	16	23	43
Minorities/ discrimination	6	7	9	9	7	13	9	51	32
Work/ employment	7	21	71	69	74	61	32	41	16
Health/ care	9	4	3	1	1	2	5	13	16
Environment	37	33	16	25	11	13	58	16	13
Living	40	27	15	23	7	3	2	6	3
Defence: war and peace	2	4	2	10	19	17	1	1	0

Table 2.12: Perception of the importance of social problems, 1971-1997[15]

Environmental awareness of people aged 18 and over (in %)						
	1989	*1994*	*1997*	*1998*	*1999*	*2000*
"Air, soil and water are already heavily polluted"	91	82	76	62	61	61
"I would be prepared to pay a little more for products to ensure clean industries"	82	80	67	66	70	68
"I'm quite willing to pay higher taxes to help improve the environment"	70	56	41	43	46	43

Table 2.13: Environmental awareness, 1989-2000[16]

[15] Source: RIVM/CBS (2001) *Dutch Environmental Data Compendium 2001* (http://www.rivm.nl/environmentaldata/).

[16] Source: RIVM/CBS (2001) *Dutch Environmental Data Compendium 2001* (http://www.rivm.nl/environmentaldata/).

The overall conclusions based on these figures could be summarised as follows [RIVM/CBS, 2001]:

- "The interest of the population aged over 18 in environmental issues is rather up and down."
- "During the 1990s interest has been declining."
- "Towards the late 1990s the continuing fall in environmental awareness of the adult Dutch population seemed to stabilize somewhat."

These figures can be considered as an indication of the "internal motivation" of consumers with respect to environmentally friendly ways of acting regarding the disposal of products that come under the Disposal of white and brown goods Decree. The objective of this Decree is closely related to reducing the air, soil, and water pollution as a result of discarded consumer electronics. In this light, the following observation is a further indication of the "sense of urgency" experienced by consumers specifically towards these problems: "In 1997 80 % of respondents were concerned about 'the environment in general,' whilst 15 % were worried about air, soil and water pollution" [RIVM/CBS, 2001].

The overall trend that can be deduced from all the above is that general interest in environmental issues and environmental awareness (willingness to invest time, money and effort) is certainly not rising and is lower nowadays than it was before. This observation implies a significant problem for a disposal system that is based on "internal motivation" as the main instigation for appropriate behaviour, especially since there are no signs that indicate any kind of swing in this trend in the (near) future.

Finally, with respect to legislation regarding the disposal and processing of consumer electronics the overall trend is 'more of the same.' In the Netherlands there are no signs of drastic alterations of current legislation in the near future, apart from the intention to formulate specific rules on how processing companies (or the NVMP/ICT Milieu) should report on the processing of collected consumer electronics. As a member of the European Union the situation in the Netherlands is also influenced by European legislation in this area. The most important development in this context is that the European Commission has adopted a proposal for a Directive on Waste of Electrical and Electronic Equipment (WEEE) and a proposal for a Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment [Commission of the European Communities, 2000]. However, at this point it is important to note with respect to the content of these proposals that they do not incorporate any specific rules or regulations that would require radical changes in the current set-up of the Product Recovery Network for consumer electronics in the Netherlands. In fact, the proposed distribution of responsibilities and obligations regarding collection, processing and financing is very similar to the Disposal of white and brown goods Decree.

2.6 Conclusions and a discussion on the weaknesses of the current system

In this Chapter, consumer electronics have been defined by means of a list of all product categories that come under the Disposal of white and brown goods Decree. Applying this definition logically results in the choice to focus the attention of the objective for the project that forms the basis for this thesis on all products on this list.

The collection and treatment of consumer electronics in the Netherlands has long since been primarily the responsibility of local authorities, as was illustrated in a condensed historical overview of waste recovery in the Netherlands.

The year 1998 forms an important turning point in waste management practice regarding consumer electronics in the Netherlands, because in that year the Disposal of white and brown goods Decree came into force. Up to that point, discarded consumer electronics caused an increasingly notable environmental problem.

In 1998 consumers discarded some 134 kiloton of used consumer electronics. The vast majority of this waste flow ended up in landfill and incineration facilities. The environmental problems resulting from this situation are mainly related to the dispersion of CFCs, a number of heavy metals, PCBs and asbestos. A considerable portion of these environmental problems, such as health risks as a result of leakages and the poor quality (toxic content) of bottom ash and fly ash coming out of incineration facilities, is caused by 'small' appliances (e.g. electrical and electronic kitchen appliances, other electrical and electronic domestic appliances and telecommunications equipment). At the same time, the majority of these appliances was disposed of by means of refuse bags/bins, which means that they end up in landfill and incineration facilities.

In an effort to tackle these problems, the Dutch government installed the Disposal of white and brown goods Decree. This Decree formulates a number of restrictions and regulations with respect to the collection and treatment of consumer electronics in order to enforce a leak proof disposal structure for this class of products.

In practice, the introduction of this Decree has resulted in the establishment of two very similar disposal structures for ICT equipment and all other consumer electronics respectively.

An analysis of available data shows that the current systems function a lot better for relatively 'big' appliances, such as TVs and cooling and freezing equipment, than for relatively 'small' appliances, such as shavers, telephones and mixers. For 'small' appliances the collection rates and reuse percentages are significantly lower than for 'bigger' ones.

In these systems the collection of consumer electronics that are set free by their former users (consumers) is still mainly the responsibility of municipalities. However, municipalities are not required to enhance collection rates. Producers and importers are obliged to take back all products handed over to them by these municipalities and process them in an environmentally sound way (as prescribed by law). However, these producers and importers are not obliged to stimulate collection or enhance collection rates. In fact,

due to the fact that higher collection rates would result in higher workload and working expenses, it could be argued that it is not in their best interest to promote more collection of used consumer electronics. As a matter of fact, the same applies to municipalities.

Consumers are supposed to dispose of their used consumer electronics by handing them over as a separate waste stream to local waste authorities or retailers. However, there is nothing in the current set-up of the disposal system to prevent them from persisting in their long since habit of throwing 'small' appliances in the refuse bag/bin. What's more, the current system incorporates no specific rewards for changing this behaviour, even though appropriate (according to the Decree) ways of acting require them to invest time, effort and sometimes even money.

This situation represents one of the major weaknesses of the current disposal system for consumer electronics in the Netherlands. The functioning of the system largely depends on the moderating role of acceptance of responsibility by consumers and a subsequent internal motivation to engage in appropriate behaviour. However, as is discussed in more detail in Chapter 5 of this thesis, research in this area has revealed that future behaviour is often not only directed by intentions (internal motivation), but also by (perceived) costs and benefits associated with that behaviour and possible barriers to engage in that behaviour, as well as past behaviour/habit [Pieters, 1989]. In the case of consumer electronics past behaviour usually refers to inappropriate behaviour and changing this pattern will require more than an "appeal to voluntary change of behaviour" [Van Meegeren, 1997].

Simultaneously, general interest in environmental issues and willingness to invest time, effort and money for general environmental benefits is at a historic low and reflects no tendency to increase in the near future.

All the above amounts to a situation in which the current Product Recovery Network for consumer electronics in the Netherlands performs worst for exactly that class of products ('small' products) that constitutes one of the biggest environmental problems. To make matters worse, the system incorporates no obvious mechanisms to alter this situation and there are no signs to indicate that things will improve autonomously.

Chapter 3

Scope, research design and characterisation of the research

3.1 Introduction

The previous two Chapters have presented an explorative analysis of the topic under discussion in this thesis (the project context). Whereas Chapter 1 described the available literature and set the stage for the remainder, Chapter 2 analysed the implementation and the environmental and economic consequences of the current Product Recovery Network for consumer electronics in the Netherlands.

This Chapter deals with the set-up of the research project on which this thesis is based and the practical and methodological background of that set-up; the so-called research design.

The next Section of this Chapter describes the original set-up of the research project, as it was proposed at the start of this project [Brombacher & De Ron, 1998]. The initial objective, research plan and research method are discussed in more detail, as are the reasons behind the choice for that set-up.

However, Section 3.3 describes how the most important findings ensuing from the literature review and the analysis of the present-day real life situation, as well as some practical developments during the carrying out of the research project, contributed to a diminishing appropriateness of this research design. It is explained how, in the course of time, achieving the original objective required adjusting the original set-up and chiefly dedicating the research efforts to one specific element of the Product Recovery Network.

In Section 4 of this Chapter, the adjusted research design, including the adjusted research method, is discussed, as well as the repercussions for the remainder of this thesis. This Chapter is concluded with a discussion on the scientific characterisation and (societal and scientific) relevance of this thesis.

3.2 The original blueprint of the research project

In Section 1.2 the objective that formed the point of departure for the research project on which this thesis is based has been presented. At the start of that project, in 1998, the Disposal of white and brown goods Decree had just been published [Staatsblad 238, 1998] and at that point in time the practical implications of the Decree were unclear. The various actors within the Product Recovery Network for consumer electronics in the Netherlands operated quite isolated and signs of co-ordination or even co-operation were certainly not omnipresent [Lemmens, 1998].

At the same time, it was concluded [Melissen & De Ron, 2001] that research in the field of Product Recovery Networks, and practical analyses and design efforts dedicated to this

area, had mostly focused on logistics aspects and only very few authors had initiated alternative approaches. Furthermore, efforts to (re)design Product Recovery Networks had focussed almost exclusively on business economical optimising of these networks from a "single actor perspective" [Brombacher & De Ron, 1998].

In an effort to assure an optimal practical (as perceived at that time) and scientific relevance of the research project, it was decided to focus the research project on redesigning the current Product Recovery Network with respect to four key (design) parameters:

1. The directness of the network, which is determined by the number of (distribution) levels in the network, and which is closely related to the way specific functions within the network are assigned to (groups of) specific actors within the network.
2. The selectivity of the network, which is determined by the number of actors at each level of the network, and which is again closely related to the way specific functions within the network are assigned to (groups of) specific actors within the network.
3. The role of the middlemen in the network, which is determined by the position of actors (including the level of co-ordination and co-operation) and the functions they perform (including the way they are performed; processes and facilities applied).
4. The number of channels within the network, which is determined by the number of parallel 'logistic paths.'

These key parameters were based on the work by Jahre [1995], Jahre & Flygansvær [1996], and Mallen [1970, reprinted in 1996] and provided an opportunity to provide uniform descriptions of various alternative Product Recovery Networks. Furthermore, applying these design parameters would enable the inclusion of aspects such as processes (collection method, reprocessing techniques) applied, number of levels, number of actors at each level, functions performed by various actors, and the level of co-operation within (parts of) the network, as well as (traditional) logistics concepts.

In order to facilitate this redesign approach, it was proposed to develop a quantitative performance model of a Product Recovery Network for consumer electronics, consisting of appropriate mathematical expressions for all relevant aspects and relations within such a network. This model should enable the analysis of relevant design alternatives (based on the key parameters mentioned above) with respect to business economic and environmental consequences for the network as a whole. In this way, this model could be used to optimise the redesign of the existing Product Recovery Network for consumer electronics and contribute to achieving the research objective: developing new concepts for organising and management.

All the above is illustrated schematically in Figure 3.1. The grey area in this Figure depicts the part of the Product Recovery Network that would be analysed by means of a quantitative performance model in order to design the 'optimal' Product Recovery Network for consumer electronics in the Netherlands. Consequently, this area represents the main subject matter of the original research design.

Summarising the above, it can be concluded that the original set-up of the research project amounted to a quantitative modelling effort as a tool to enable the redesign of the Product

Recovery Network for consumer electronics in the Netherlands, especially with respect to the assignment of functions, the choice for specific (end-of-life) processes and facilities, and the level of co-ordination and co-operation between the various actors involved in this network.

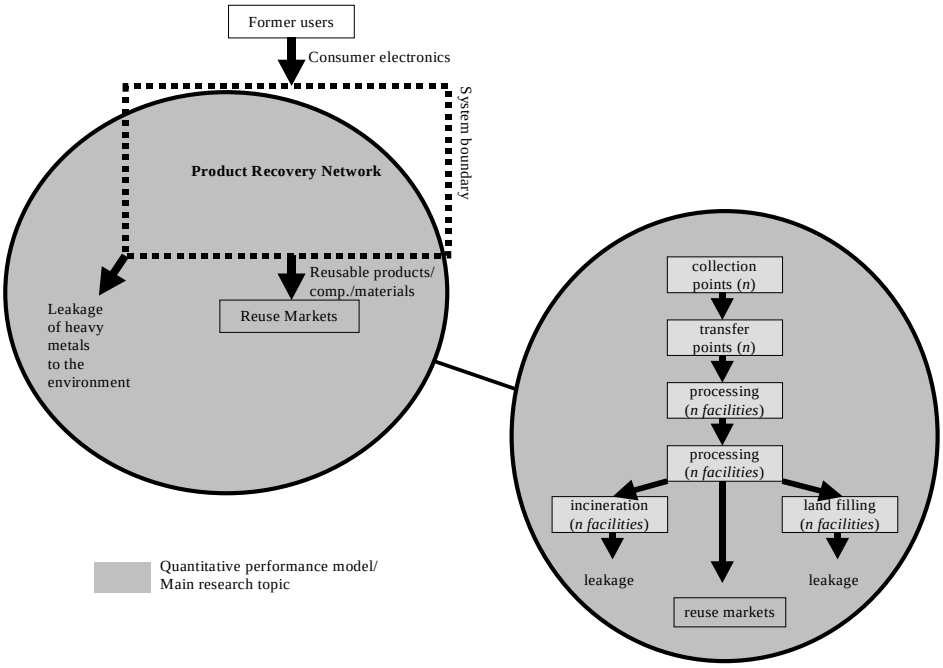


Figure 3.1: Schematical overview of original research design

3.3 The need for adjustments with respect to research design/method

From the literature review presented in Section 1.3 and especially the analysis of the current Product Recovery Network for consumer electronics in the Netherlands presented in Chapter 2, it is apparent that the point of departure for the research project on which this thesis is based has changed quite considerably compared to the situation in 1998. In fact, a convincing argument can be made to state that the happenings in the course of time have overtaken the original set-up of the project and diminished the appropriateness of this research design and the selected research method.

At the start of the project, the consequences in practice of the Disposal of white and brown goods Decree were still unclear and the set-up of the Product Recovery Network for consumer electronics in practice was still indistinct. Initiatives to engage in co-ordination and co-operation between the various actors in the network were scarce and indefinite. Therefore, the choice for a research approach that mainly focused on optimising the network composition with respect to these aspects, as well as logistics aspects, was a logical one.

However, the developments in time now show a quite different point of departure for this thesis. All kinds of co-ordination and co-operation initiatives, involving almost all actors involved in the disposal of consumer electronics, have eventuated in a very stable disposal structure for the current Product Recovery Network. Importers and manufacturers work together in and are represented by the NVMP and ICT Milieu. These organisations have involved a fixed group of processing companies and carriers in the execution of end-of-life treatment and transport of collected consumer electronics. The collection stage of the network is dominated by the role of municipalities, also to a large extent relying on co-ordination and co-operation efforts, which has resulted in the realisation of Regional Storage Stations.

This current composition of the Product Recovery Network for consumer electronics in the Netherlands, which has been described in more detail in Chapter 2 of this thesis, appears to be quite stable for a number of reasons.

First of all, the way the NVMP and ICT Milieu attend to the responsibilities of importers and manufacturers has been approved by the Dutch government. Similarly, the way municipalities have organised the execution of (part of) their responsibilities by means of Regional Storage Stations is in compliance with a governmental manual on this topic [Informatiecentrum Preventie en Hergebruik, 1998]. With respect to collection obligations and processing prescripts for municipalities and producers (represented by the NVMP and ICT Milieu) respectively, Chapter 2 indicates that these tasks are executed in conformance with the law and at the same time this law does not incorporate any stimulations for these actors to engage in additional efforts to improve on their current performance. Therefore, there is no urgency or instigation for any changes from a legislational perspective.

Secondly, Chapter 2 already indicated that the current set-up of the disposal structure for consumer electronics results in minimal financial burdens for municipalities and producers. The introduction of Regional Storage Stations has resulted in considerable savings for municipalities and, at the same time, they receive fees from retailers and repair companies and a financial contribution from the NVMP and ICT companies. The only financial burden for producers in the NVMP system consists of handing over the disposal levy that they receive from customers, whereas companies in the ICT sector are required to pay the invoices send to them by ICT Milieu. The latter have the freedom to increase their selling prices to provide the financial means to bear these costs. This situation amounts to the NVMP currently having more financial means at its disposal than ever intended and ICT Milieu simply sending all the bills to the companies coming under their system. From all this, it can be concluded that there is no urgency for any changes from a financial perspective for the actors involved in the current Product Recovery Network in practice.

Thirdly, lagging environmental gains could form a final instigation for specific changes in the current system. However, the present-day disposal structure clearly is the result of ‘complying with legislational boundaries’ and not of some ‘manifest desire by municipalities and companies alike’ to take measures with respect to the environmental problems stemming from the disposal of discarded consumer electronics, as was discussed in Subsection 2.3.2. Recent years have not shown any signs of a sudden change of hart of any of the actors within the current Product Recovery Network in practice and therefore there is no urgency or instigation for any changes from an environmental perspective for the actors involved.

Therefore, a research approach that focuses specifically on optimising the Product Recovery Network for consumer electronics by means of developing (a quantitative performance model to assist in designing) new ways of assigning tasks, new ways of co-ordinating the execution of these tasks and new ways of co-operation with respect to this execution now seems rather inadequate as a means of making a maximum contribution to optimising this network and thereby closing the life cycle of consumer electronics.

What's more, the analysis presented in Chapter 2 clearly indicates that one of the most obvious (remaining) problems with respect to the current Product Recovery Network for consumer electronics in the Netherlands is not (obviously) related to general co-operation or co-ordination deficiencies within the network. A major weakness of the current system, at least from an environmental perspective, is related to the role of a group of actors that are not included in this network, consumers, and the way the network is (un)able to regulate and respond to the behaviour of this group. As was concluded in the previous Chapter, the functioning of the current disposal structure largely depends on the moderating role of acceptance of responsibility by consumers and a subsequent internal motivation to engage in appropriate behaviour. This dependency and further problems in the processing stages [Lemmens, 1998] have resulted in a situation in which the current system functions faulty for a specific class of products, i.e. 'small' consumer electronics.

On the one hand the collection rate for this particular 'type' of products is significantly lower than for other products, and on the other, the reuse percentage for this 'type' of products is also significantly lower than the reuse percentage for other product categories. To make matters worse, these particular products ('small' consumer electronics) constitute a considerable portion of the environmental problems resulting from inappropriate disposal and treatment [Staatsblad 238, 1998].

From all the above and the analysis presented in Chapter 2 of this thesis it becomes evident that actually contributing to closing the life cycle for consumer electronics would clearly benefit from addressing the following two main problems:

1. The apparent inaptness of the (changeover to the) current Product Recovery Network for consumer electronics to ensure 'adequate' collection rates for 'small' consumer electronics and to prevent these products from ending up in refuse bags/bins.
2. The apparent inaptness of current end-of-life treatment processes within the Product Recovery Network for consumer electronics to ensure 'adequate' reuse percentages.

The second problem mentioned above is dealt with in two other research projects within the grouping of projects (the IOP-project mentioned in Section 1.2 of this thesis) that aims at contributing to closing the life cycle for consumer electronics. In fact, at this point, it is important to note that the remaining three subprojects within the IOP-project specifically aim at "bringing about technological breakthroughs" [Lemmens, 1998] and adjustments in the product design stage of consumer electronics (to facilitate these breakthroughs). All these efforts are aimed at realising further enhancements of the Product Recovery Network for both 'big' and 'small' consumer electronics with respect to minimising the leakages of heavy metals to the environment from this network, once these products have been (separately) collected.

The first problem mentioned above touches upon the collection stage of the Product Recovery Network for consumer electronics and forms an integral part of the topic (the project context) of the research project on which this thesis is based. Therefore, based on the findings of Chapter 2 and the analysis presented above, and as a result of the wish to make a maximum contribution to the attainment of the overall objective of the grouping of projects, the original research approach of this research project had to be adjusted.

Subsection 1.3.3 of this thesis already revealed that the collection stage of a Product Recovery Network seems to be neglected in scientific research and literature, even though the importance of this stage is widely accepted and postulated. The arguments presented above illustrate and underwrite this conclusion once more. Therefore, adjusting the original research approach of this project and focussing specifically on the collection stage of the Product Recovery Network for consumer electronics is not just warranted from a societal perspective, but also enhances the scientific relevance.

Adjusting the original research approach and focussing specifically on the collection stage also boils down to an adjustment in the research method applied. Whereas the original research method, the development of a quantitative performance model, seemed the appropriate means to design new concepts for the assignment of tasks, co-ordination and co-operation, the adjustment of the focus of the research project to the collection stage requires the application of different research methods. The collection stage contains the fine-tuning of the junction between the consumers that set free used consumer electronics and the Product Recovery Network that absorbs and processes these products. Enhancing collection rates and establishing subsequent managerial and organisational (or even political) constraints and consequences requires an analysis that also considers consumer behaviour and appropriate means to influence this behaviour. Obviously, the choice to engage in such an analysis eventuates in the application of different research methods. This conclusion constitutes the point of departure for the next Section, which deals with the choice for an appropriate research design with respect to this altered situation.

3.4 The final research design: focussing on the collection stage of the PRN

Even though the previous Section clearly illustrates the need for adjusting the focus and approach of the research project that forms the basis for this thesis, the basic point of departure for this project, i.e. the general objective, remains the same:

General objective for the project (project context)
To contribute to closing the life cycle of consumer electronics, especially with respect to heavy metals, by developing new concepts for organising and managing the Product Recovery Network for consumer electronics that could contribute to optimising this network from a business economic and environmental perspective.

However, based on all the foregoing, making such a contribution and the wish to make a maximum contribution to the attainment of the overall objective of the grouping of projects are best served by focussing the research efforts on the collection stage of the Product Recovery Network for consumer electronics in the Netherlands, or more precisely, addressing the fine tuning of the junction between the consumers that set free used ‘small’

consumer electronics and the Product Recovery Network that absorbs and processes these products.

This distinction between the 'general' objective for the research project and the 'specific' focus of the research efforts within this project demarcates the specific *contribution* [Verschuren & Doorewaard, 1999] of this thesis to the attainment of the overall objective of closing the life cycle for consumer electronics.

From all the above (including Chapter 2 and Section 3.3), the following research objective for this project can be derived:

Project research objective
To design appropriate measures for fine tuning the junction between consumers that set free used consumer electronics and the Product Recovery Network that absorbs and processes these products, in order to enhance collection rates, specifically with respect to 'small' products.

The above represents a clear adjustment of the focus of the research efforts in comparison with the original research approach described in Section 3.2. All the above is illustrated schematically in Figure 3.2. The dark grey area in this Figure depicts the part of the Product Recovery Network that constitutes the main subject matter of the research project (the problem that is analysed), whereas the lighter grey area pertains to the measures that need to be designed (possible solutions).

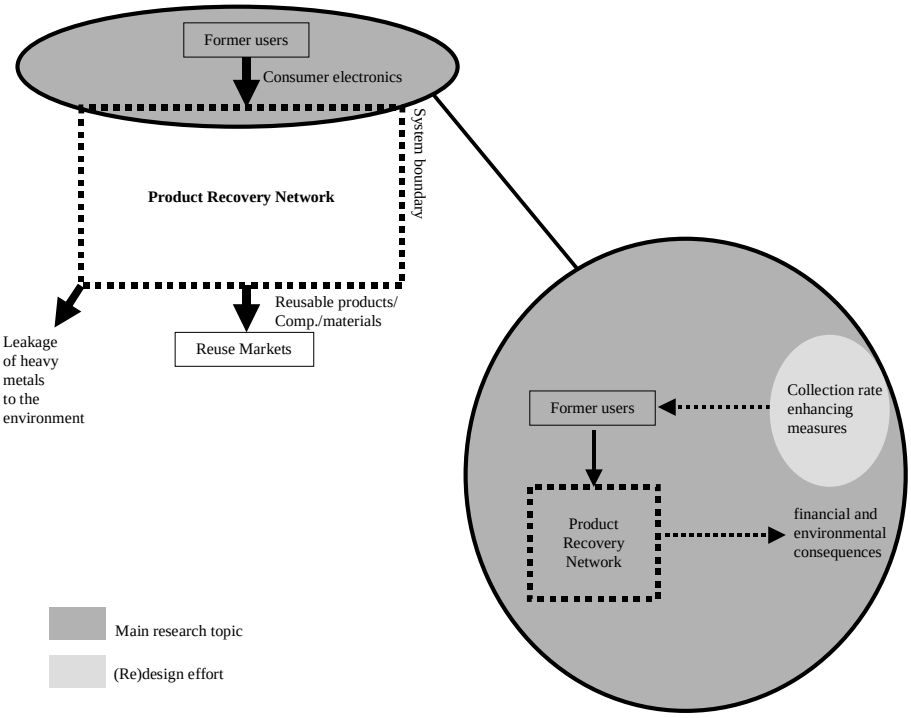


Figure 3.2: Schematical overview of the adjusted research design

As described before, the original research design also included a (re)design process. However, the difference between the subject matters that need to be analysed definitely requires a different method to be applied in the adjusted research approach. The adjusted research design and subsequent design effort focus on human behaviour and measures to influence this behaviour in a predetermined direction. The nature of this topic clearly does not lend itself for mathematical simulation. Furthermore, the subject matter and the circumstances surrounding the research project and the current Product Recovery Network in practice do not allow for any sort of extensive testing of prototypes. In fact, a practical prototype of behaviour influencing measures seems a somewhat fictitious concept altogether. Therefore, the search for an appropriate research method in the adjusted research project resulted in the choice for a thorough desk research, addressing the analysis of the current situation, the generation of (re)design alternatives and the evaluation of consequences in (future) practice by means of analysing existing literature and available empirical data. The latter includes the reports and additional data with respect to a limited number of pilot projects initiated by the Dutch government and the NVMP. These data provide (and complement) this desk research effort, and the enclosed design process, with a clear practical component (case studies).

The design process itself has been divided into three generic stages[1]: analysis, synthesis and evaluation [Jones, 1981/1984].

The *analysis* stage (as a logical continuation of the *problem analysis* presented in Chapters 1 to 3) comprises an analysis of pilot projects in this area (Chapter 4) and theory with respect to consumer (disposal) behaviour and appropriate ways of influencing this behaviour (Chapter 5).

This is followed by the *synthesis* stage (Chapter 6), in which the lessons that can be learned from practice (based on the findings of Chapters 2 and 4) and theory (based on the findings of Chapters 1 and 5) are applied to generate design alternatives, i.e. alternative measures to enhance the collection rates for consumer electronics, especially with respect to 'small' products.

The design process continues with the *evaluation* stage in Chapter 7, in which the various design alternatives are evaluated with respect to (practical) feasibility and the expected (business) economic and environmental consequences (collection rates). These last two criteria provide a clear back coupling to the general objective of the research project.

Based on this design process and a subsequent 'political analysis' (Chapter 8) that is closely related to the societal feasibility of specific measures, Chapter 9 winds up the discourse presented in this thesis by means of presenting the main conclusions and recommendations.

All the above can be summarised schematically, as follows (Figure 3.3):

[1] A more detailed description of the specific steps that need to be effectuated to cover these stages [Cross, 1994] is given in Chapter 6.

A bird's-eye view of this thesis:

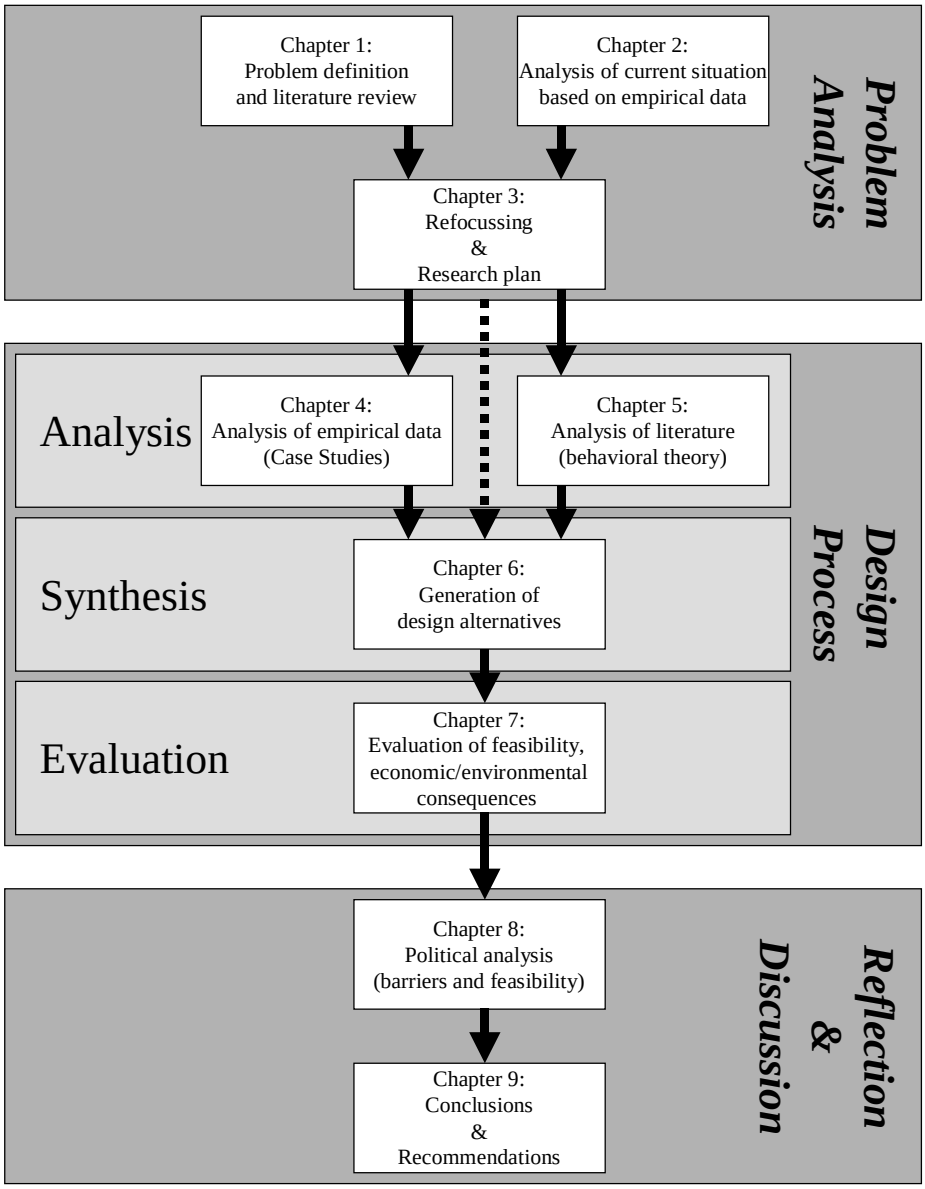


Figure 3.3: Schematical overview of the research plan

3.5 Characterisation and relevance of this project/thesis

The previous Sections have accounted for the contents of (the remainder of) this thesis and the reasons behind the choices that have been made. Before addressing the analysis stage of the design process itself (Chapters 4 and 5), this final Section explicitly establishes the societal and scientific 'status' (relevance) of the analysis presented in this thesis.

3.5.1 Societal relevance

The societal relevance of the research project on which this thesis is based has been illustrated extensively in all the foregoing. The fact that a significant portion of all discarded 'small' consumer electronics still ends up in incineration facilities for regular household waste, which results in continued leakages of heavy metals to the environment, poses a clear societal problem[2] (public health risk) that certainly deserves a (re)search effort with respect to possible solutions.

A further illustration of the context of this particular problem could be based on a characterisation within the framework of the IOP-project mentioned before (the overall project of which the research project on which this thesis is based is part of).

One of the four subprojects within this IOP-project specifically focuses on realising adjustments in the product design of consumer electronics in order to facilitate 'new' or 'improved' end-of-life treatment processes for consumer electronics. Two other subprojects are dedicated to bringing about these 'new' and 'improved' processes. Obviously, for these three subprojects to have a significant effect on "closing the life cycle for consumer electronics, especially with respect to heavy metals" [Lemmens, 1998] one specific condition that at least needs to be met is that these consumer electronics actually end up in these 'new' and 'improved' processes. In other words, consumer electronics need to be collected separately and transported to the facilities that perform these dedicated (to consumer electronics) end-of-life treatment processes (see Figure 3.4).

[2] Determining the exact magnitude of this problem is the topic of one of the three other subprojects within the IOP-project and lies beyond the scope of this thesis. However, the fact that the Dutch government has introduced legislation specifically dedicated to the environmental problems caused by consumer electronics and refers specifically to the problems caused by 'small' consumer electronics ending up in incineration facilities for regular household waste constitute clear points of reference for the significance of this problem in the eyes of the Dutch government. This thesis joins with this assessment, also based on the preliminary results of the above-mentioned subproject dedicated to a scientific adjudication of this problem.

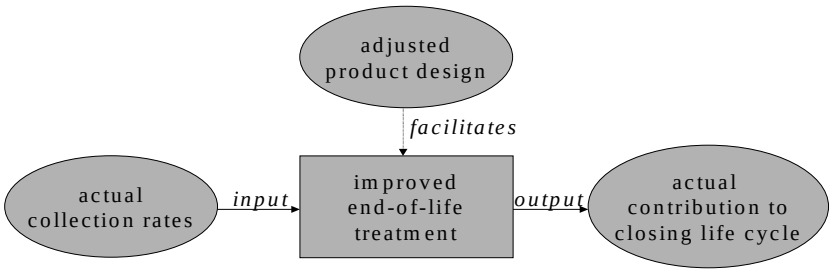


Figure 3.4: The contribution of collection rates to the objective of the IOP-project

Chapter 2 of this thesis has revealed that for 'big' consumer electronics current (separate) collection rates are high, with the exception of 'big' white goods. The latter poses a specific problem that is related to the high positive value of recyclable materials in these products [PriceWaterhouseCoopers, 2001], resulting in a relatively large portion of these products being sold (exported) in the recycling branch, and that is discussed in more detail (including proposals for possible solutions) in [De Koster et al., 2002].

For 'small' consumer electronics current collection rates are low, which means that for this particular product category the above-mentioned condition is, to a large extent, not met. This thesis deals with a design-oriented research that aims at designing (policy) measures that could resolve this issue. Obviously, this characterisation constitutes a further illustration of the practical/societal relevance of this thesis, but it also encompasses a first reference point for establishing the scientific relevance of this thesis.

3.5.2 Scientific relevance

It would be reasonable to assume that the condition mentioned above, with respect to products needing to be actually collected, constitutes a key condition for (many) research projects dedicated to optimising Product Recovery Networks. The solutions that are developed in this thesis, and especially the way in which they are derived, could serve as a reference point for addressing this condition beyond the boundaries of this particular thesis. The relevancy of this focus/approach can be illustrated by referring to the survey of relevant literature in Chapter 1 of this thesis. That survey has revealed that literature and (previous) research dedicated to Product Recovery Networks have dealt with the latter (end-of-life treatment) stages of these networks extensively. Simultaneously, even though the importance of this stage is recognised and acknowledged, the actual collection stage of a Product Recovery Network seems to be neglected and is treated as a given. Therefore, the specific focus of this thesis on this particular stage of the Product Recovery Network for consumer electronics in the Netherlands could contribute to the much-needed further exploration of this key element of Product Recovery Networks in general.

The passage mentioned above, i.e. “the way in which they are derived,” is directly linked to a second key element of the scientific relevance of this thesis. Not only the topic itself, but the approach to dealing with this topic could be deemed ‘innovative.’

As mentioned in Chapter 1, this thesis represents a practice-oriented research that encompasses a *design-oriented research* [Verschuren & Doorewaard, 1999] that focuses on designing collection rate enhancing measures for ‘small’ consumer electronics.

All this means that, based on the objective to include all “essential aspects that must be incorporated” [Cross, 1994] in the measures that are designed to enhance collection rates for ‘small’ consumer electronics in the Netherlands, in other words to ensure the ‘completeness’ and effectiveness of these measures, this thesis embraces a structured design effort to derive appropriate solutions for the problem established above.

This approach, applying the division in three generic design stages by [Jones, 1981/1984] and the design methodology by [Cross, 1994](see Chapter 6) to address the specific steps that need to be effectuated to cover these stages, constitutes a rather uncommon procedure with respect to developing (policy) measures to influence consumer behaviour (see Chapter 5). Furthermore, within the framework of this design methodology, this thesis combines a so-called ‘psychological (meta-) model’ (in the analysis stage) with a design method (in the synthesis stage) that is usually applied to design tangible products; the Triad model (see Chapter 5) and the Morphological Chart Method (see Chapter 6) respectively. In effect, this psychological conceptual model (the Triad model) is applied to establish all “essential aspect that must be incorporated” [Cross, 1994] in the design alternatives and, subsequently, the ‘technical’ design tool (Morphological Chart Method) is applied to ensure that all of these aspects actually are included in the design alternatives that are generated.

Therefore, this thesis could contribute to a (first) adjudication of the appropriateness and practical applicability of such an approach and included methods for the development of effective (intangible) policy measures to influence consumer behaviour. Chapter 9 addresses the experiences with applying this approach within this particular thesis and advances a first appreciation of the possibilities for “generalisation” [Van Harten, 1999].

Chapter 4

Enhancing collection rates for 'small' consumer electronics

Empirical data derived from pilot projects

4.1 Introduction

This Chapter is composed of a description of a number of pilot projects dedicated to the collection of discarded consumer electronics, especially 'small' products, and an analysis of the lessons that can be learned from these case studies. The latter focuses on constraints and contingencies that could play an important role in the generation of design alternatives for collection rate enhancing measures in Chapter 6 and the evaluation of these alternatives in Chapter 7 of this thesis.

In the remainder of this Chapter the subsequent pilot projects are presented, and the most telling results (e.g. resulting collection rates, costs involved) and the most apparent conclusions that can be drawn from these results are depicted. A general overview of these conclusions, especially regarding the effectiveness of specific measures with respect to enhancing collection rates for 'small' consumer electronics, and an analysis of the bearings on the design process presented in this thesis conclude this discussion.

4.2 Pilot project 1: Apparetour (1997)

One of the first pilot projects in the Netherlands with respect to the collection of consumer electronics was the so-called "Apparetour"-project. This project was initiated in 1994 by SRE (Samenwerkingsverband Regio Eindhoven ~ Co-operating Municipalities in the region Eindhoven), FIAR (branch organisation of brown goods importers and producers) and VLEHAN (branch organisation of white goods importers and producers), based on a sense of responsibility for the collection and processing of (their brand of) discarded products and the wish to anticipate on possible future legislation. The set-up of this project included three separate subprojects: (1) Collection & Logistics, (2) Selection (sorting) & Repair, and, (3) Disassembly & Reuse of materials.

With respect to the topic of this thesis, the first of those three subprojects is by far the most interesting and is discussed below, based on the report by the consultancy firm that was hired to co-ordinate and support the execution of the project [Klompers et al., 1997].

Set-up of Apparetour/Collection

The objectives for the subproject dealing with collection and logistics (referred to as "Apparetour/Collection" in the remainder of this Section) were defined as follows:

1. To gain more insight with respect to the collected amount of equipment within Apparetour and the costs involved.
2. To investigate the possibilities for setting up a collection system that could function without leakages.

Apparetour/Collection was carried out in the region Eindhoven, with 29 municipalities (640,000 inhabitants) participating. Most of these municipalities constitute rural areas, apart from Eindhoven itself, which is a city of 196,000 inhabitants. The number of consumer electronics selling retailers amounts to about 150, of which 45 have participated in the project.

The consumer electronics that were collected in Apparetour/Collection were divided up into 6 categories: (1) (H)CFC containing consumer electronics, (2) 'Big' white goods, (3) 'Small' white goods, (4) Brown goods with screen (tube), (5) Brown goods without screen (tube), and, (6) 'Small' domestic appliances.

The collection routes applied in various clusters of municipalities eventuated in 5 specific scenarios/schemes that could be 'measured' and analysed, which are reflected in Table 4.1 below (each cluster represents several municipalities that applied the same collection routes):

Collection route	*cluster 1a*	*cluster 1b*	*cluster 2*	*cluster 3*	*cluster 4*	*cluster 5*
consumers and retailers bring used products to the municipal waste yard	x	x	x	x	only consumers	
retailers bring used products to a separate depot					x	
used products are collected at retailers	weekly	monthly	weekly			
used products are collected at consumers	4 times / year	monthly				
'small' domestic appliances are collected together with 'small' chemical waste					4 times / year	
recycling store						x

Table 4.1: Collection routes applied and analysed in Apparetour/Collection

Results and conclusions from Apparetour/Collection

The Apparetour/Collection project included a number of measurements, additional surveys and enquiries to enable the researchers to analyse the adequacy of specific (groupings of) collection routes and interpret the results. The remainder of this Section reflects some of these results and the most important conclusions that were established.

Within Apparetour/Collection, Clusters 1a and 1b contain the biggest variety of collection routes (see Table 4.1), with two curbside collection services, and the results show that these two clusters also acquire the highest collection rates (see Table 4.2).

collection rate	*cluster 1a*	*cluster 1b*	*cluster 2*	*cluster 3*[1]	*cluster 4*	*cluster 5*
'big' appliances	78.2 %	76.6 %	53.8 %	22.4 %	24.6 %	31.2 %
'small' appliances	26.6 %	29.4 %	26.5 %	8.1 %	2.3 %	8.0 %
total for all appliances	39.0 %	40.7 %	33.0 %	11.6 %	7.6 %	10.3 %

Table 4.2: Collection rates (related to the theoretical amount of disposed consumer electronics) for the 6 clusters within Apparetour/Collection

Therefore, it was concluded from the collection results within Apparetour/Collection that *the higher the number of alternative collection routes and the higher the service provided to consumers and retailers, the higher the collection rates that can be achieved*.

The latter is confirmed by the fact that the clusters with higher frequency of the collection service provided by the municipality score significantly better, both for collection services provided to retailers and consumers. Another confirmation for this conclusion is presented by the fact that retailers are willing to hand over collected consumer electronics to second-hand dealers and recycling stores that provide a collection service, whereas municipalities (clusters) that do not provide such a service report that retailers are not bringing any collected products to the municipal waste yard.

By means of a survey amongst consumers (inhabitants) [Van Pol, 1996], it was determined that the main mode of communication to consumers applied within Apparetour/Collection, advertisement in local door-to-door magazines, was relatively unsuccessful. Whereas 45 % of inhabitants of the region Eindhoven reported that they were aware of Apparetour/Collection and its objectives, only 14 % indicated that they received this information by means of this specific campaign. What's more, this survey revealed that the number of advertisements and articles had no significant bearing on the number of inhabitants that was aware of the project. Therefore, it could be concluded from this specific pilot project that *advertisements and articles in local door-to-door magazines as a means to communicate with consumers with respect to the separate collection of consumer electronics seems inadequate*.

[1] During the project two specific municipalities were excluded from this cluster and reassigned to a 'new' cluster; cluster 3a. The collection rates reported for this cluster were: 48.4 %, 24.3 % and 30.1 % respectively.

The above-mentioned survey was not the only research effort directed specifically at the attitudes and behaviours of consumers. In fact, within the framework of Apparetour/Collection, three separate surveys ([Van Pol, 1996], [Bertens et al., 1997] and [Steenwinkel et al., 1997]) were carried out amongst the consumers/inhabitants of the region Eindhoven. The results of these surveys and the collection results within Apparetour/Collection reveal a clear problem with respect to the collection of 'small' consumer electronics.

With respect to the distinction between 'big' and 'small' appliances the results of Apparetour/Collection display an overall picture that resembles the situation described in Chapter 2, the situation after the Disposal of white and brown goods Decree came into force. Whereas the collection rate for 'big' appliances is 31.9 % of the theoretical amount (based on an estimation) of disposed products, the collection rate for 'small' appliances is only 9.2 %. These results are similar for all clusters. Therefore, it could be concluded that *the collection routes applied in Apparetour/Collection seem more adequate for 'big' consumer electronics than for 'smaller' appliances*.

The three surveys mentioned above revealed some specific observations that could contribute to explaining this distinction. In all three surveys, consumers were asked to indicate the most relevant disposal routes for them for specific product categories (Table 4.3):

Survey	*(H)CFC containing consumer electronics*	*brown goods*	*'small' white goods and 'small' domestic appliances*
[Van Pol, 1996]	retailer municipality	retailer municipality	municipality refuse bag/bin
[Bertens et al., 1997]	retailer municipality	municipality retailer	municipality retailer
[Steenwinkel et al., 1997]	n/a	municipality refuse bag/bin (only products without screen)	municipality refuse bag/bin

Table 4.3: Most relevant disposal routes indicated by consumers

Consumers indicate that for 'small' consumer electronics they consider the refuse bag/bin as a convenient and customary disposal route, even though they still indicate to prefer handing them over to the municipality. However, two of these surveys ([Van Pol, 1996] and [Steenwinkel et al., 1997]) also asked the same consumers to indicate how many appliances they had disposed of in the last year. From this particular enquiry it became clear that consumers overestimate the number of 'small' appliances that they have handed over to the municipality by some 35 %. Simultaneously, the collection results from Apparetour/Collection revealed an unaccounted-for amount of 'small' consumer electronics of some 190,000. A sorting analysis of domestic refuse that was carried out as part of the project [Heidemij Advies B.V., 1997] confirmed the surmise that most, if not all, of this quantity ended up in refuse bags/bins. Therefore, one of the most important conclusions from Apparetour/Collection was put into words as follows: *As long as consumers cannot be*

persuaded to change their custom behaviour of disposing of 'small' consumer electronics by means of the refuse bag/bin, efforts to enable separate collection of consumer electronics will have limited results with respect to this specific product category.

With respect to this particular problem, one final observation from Apparetour/Collection most certainly deserves mentioning at this point. In Geldrop, one of the participating municipalities, a special campaign [Visser et el., 1997] to enhance the collection of 'small' appliances by means of curbside collection resulted in a considerable amount of 'extra' collected 'small' appliances. Therefore, it was concluded that *applying additional publicity campaigns and curbside collection (combined with door-to-door efforts to persuade people to participate) can result in significantly higher collection rates for 'small' appliances and prevent these products from ending up in refuse bags/bins*.

This last conclusion winds up the discussion of the Apparetour/Collection project. It is important to note at this point that this project was carried out before the Disposal of white and brown goods Decree came into force. Therefore, some of the conclusions mentioned above seem rather obvious, especially in light of the analysis presented in Chapter 2 of this thesis. However, Apparetour/Collection constitutes the first major pilot project in the area of collection of consumer electronics and still contains a number of possible indications that could form important reference points for the design process described in this thesis.

4.3 Pilot project 2: Collection by means of the "WeBbak" (1999)

This project was carried out over a 12 month period in 5 municipalities in the North-East of Groningen (a Dutch province): Bellingwedde, Vlagtwedde, Veendam, Winschoten and Hoogezand Sappemeer. The focal point in this project was the so-called "WeBbak," a white and brown goods (street-)container, very similar to the ones already applied in the Netherlands to collect used clothing (that is usually send to developing countries).

The objective of the WeBbak-project was to investigate the possibility of applying such a container as one of the collection routes within the framework of the Disposal of white and brown goods Decree, especially with respect to 'small' consumer electronics. Besides establishing a clear outlook on conceivable collection rates, this project aimed at gaining more insight into the costs involved, the required communication with consumers and third parties, and some specific technical issues (beyond the scope of this thesis).

In the remainder of this Section, an overview of the set-up and the main results and conclusions associated with the WeBbak-project are presented, based on the report by the (consultancy) firms that were hired to co-ordinate and support the execution of the project [Projectburo Hergebruik NO-Nederland et al., 1999].

Set-up of the WeBbak-project

In first instance, 10 WeBbak containers were situated in the participating municipalities and at a later stage 4 more were placed. An important distinction between the participating municipalities consisted in the fact that in Winschoten and Hoogezand Sappemeer these containers were placed at the municipal waste yard, whereas in the other municipalities the containers were placed in the streets of the town, close to parking lots or shopping malls.

The project specifically aimed at collecting 'small' domestic appliances, practically defined in the project as "all appliances that have a plug and/or battery, and that fit into a shopping bag." The reason for the latter lies in the fact that the opening of the WeBbak container does not allow for bigger appliances to be thrown in.

The WeBbak containers have a swing lid at the bottom to let the collected products drop into the truck when the containers are emptied. As a consequence, the products that are collected by means of a WeBbak get damaged and contaminated, which makes them unsuitable for product reuse.

Results and conclusions from the WeBbak-project

The WeBbak containers resembled the containers that are usually applied in many municipalities in the Netherlands to collect used clothing. The result of this similarity was that the WeBbak containers contained some clothing bags in the first few months of the project. To stop this contamination stickers were placed on the containers with the text: "Do not throw in clothing." This step resulted in a clear reduction in the number of clothing bags thrown in the WeBbak containers.

The products thrown in the WeBbak containers also embodied other contaminations, such as deep fryer grease, batteries and vacuum cleaner bags. The contaminations lead to some problems in the processing stage, resulting in additional costs, but the material streams after shredding still proved to match the streams resulting from processing consumer electronics that are collected in another way.

All the above, the way of emptying the WeBbak containers and the contaminations, resulted in the following conclusion: *Consumer electronics collected by means of the WeBbak container are unsuitable for product reuse purposes; they are suitable for material reuse purposes, however this requires additional expenditures in comparison with other collection routes*.

The collection rate obtained by means of the WeBbak container amounted to 9.9 % of the theoretical amount of disposed consumer electronics. With respect to this percentage, it is important to note that the average weight of collected products was significantly higher than the average weight of 'small' consumer electronics collected in Apparetour/Collection. Therefore, the following conclusion seems warranted: *Applying WeBbak containers as a collection route results in moderate collection rates in comparison to other means of collection and seems inadequate to gain control over the 'smallest' appliances*.

Another noteworthy observation relates to the differences in collection rates for the individual municipalities participating in this project. Whereas in Vlagtwedde, Bellingwedde and Veendam some 296 kilograms per 1000 inhabitants per year was collected, the collected amount in Winschoten and Hoogezand Sappemeer was only 104 kilograms. Therefore, it can be concluded that: *The placing of the WeBbak container correlates with the resulting collection rate; WeBbak containers near parking lots and shopping malls result in significantly higher collection rates than WeBbak containers at a municipal waste yard*.

4.4 Pilot project 3: Combining a reward with a convenient bring system (1999)

In 1999, the municipality of Delft and the Ministry of VROM (Housing, Spatial Planning and the Environment) initiated a pilot project to investigate the effect on collection rates of combining a reward system with a convenient bring system for the collection of 'small' consumer electronics. This pilot project was carried out in the period September to December 1999 in Delft.

In the remainder of this Section, an overview of the set-up and the main results and conclusions associated with this project (henceforth referred to as the Delft-project) are presented, based on the report by the consultancy firm that was hired to co-ordinate and support the execution of the project [De Straat Milieu-adviseurs B.V., 1999].

Set-up of the Delft-project

In this project consumers were given the opportunity to hand in their used 'small' consumer electronics at 11 supermarkets (out of a total of 24 supermarkets) in Delft and they received a reward for doing so. At those supermarkets, mini containers (140 litres) were placed to collect the appliances brought in by the clientele. These mini containers were emptied each week, or on call. Usually the mini container was situated either at the retourette for bottles, or at the cigarette counter.

One of the main objectives of the Delft-project was to analyse the effect of combining such a bring system with measures to stimulate collection rates; a reward system. Based on some practical considerations, this reward system was effectuated by means of a lottery. Consumers that handed in their used 'small' consumer electronics received a lottery ticket for each appliance handed over. The prize was made up of a bicycle.

Inhabitants of Delft were informed of this project by means of free publicity, advertisements in local newspapers, and leaflets and posters. The message contained information about the environmental gains of separate collection of consumer electronics and practical information about the placement of the mini containers, the maximum size of products that should be handed in and the lottery (prize). One recurring slogan formed the central point of all communication within this campaign: "Your old appliance for a new bicycle." This means that the lottery formed the focal point of attention, instead of the environmental consequences or some sort of call upon joint responsibility.

Results and conclusions from the Delft-project

Considering the fact that this project only involved one collection route, the resulting collection rate that was achieved during the project was remarkably high: 29.1 % of the theoretical amount of disposed 'small' consumer electronics. The success rate of this collection route is even more striking if it is considered that not all supermarkets in Delft participated. Therefore, not all inhabitants of Delft were given the opportunity to hand over their used consumer electronics in their local/preferred supermarket.

In Apparetour/Collection the collection rate for 'small' appliances was only similarly high in one of five clusters, which combined a number of collection routes, including curbside collection. In the WeBbak-project the resulting collection rate was as low as 9.9 % and

results were even worse for the 'smallest' product categories. The latter certainly does not apply for the Delft-project.

Based on the above considerations, it can be concluded that *the collection route applied in the Delft-project, a convenient bring system combined with a reward system, results in a remarkably high collection rate, compared with other pilot projects, and seems just as adequate for the 'smallest' product categories.*

Over 90 % of the customers handed in one appliance, but some people handed in as many as ten or more (one person even handed in 55). This could mean that the reward involved with handing in used products stimulated some to collect many products.

Simultaneously, a survey that was carried out within the framework of the Delft-project revealed that over 50 % of the people that were aware of the pilot project indicated that the reward system stimulated them to bring used consumer electronics to the collection points in the participating supermarkets. Some 30 % indicated that they would have done that anyway, even without a reward. The same survey showed that people considered the supermarket a convenient place to hand over used consumer electronics. Therefore, it was concluded that *supermarkets are considered to present a convenient collection point for 'small' consumer electronics by consumers, and the reward system applied in the Delft-project enhanced collection rates.*

The final striking observation related to the Delft-project refers to the costs involved with this project. The final report mentioned that the actual collection costs directly related to the 'small' consumer electronics collected at the supermarkets amounted to 4,900 Dfl. (~2200 Euro). Simultaneously though, the separate collection of these 'small' consumer electronics reduced the total amount of regular household waste that needed to be incinerated by some 13.4 ton and increased the fees the municipality received from the NVMP for collected products handed over to them. In total, this resulted in a savings of 3,160 Dfl. (~1400 Euro) and additional revenues of 2,680 Dfl. (~1200 Euro) for the Delft municipality. In practice, this pilot project and the collection route applied resulted in a financial surplus for the Delft municipality with respect to costs and revenues directly related to collection and processing activities. However, it is important to note that combining this collection route with a reward system resulted in additional costs for prizes and communication. Nevertheless, one striking observation that is usually ignored in other pilot projects, could be phrased as follows: *A bring system for 'small' consumer electronics, as described in the Delft-project, with collection points located at supermarkets, results in actual collection costs that are equal or even lower than the savings and additional revenues for the municipality involved.*

4.5 Pilot project 4: Retailer Collection System (2000)

From June through November 1999, in the municipality Heemskerk a pilot project was carried out with respect to the collection of 'small' domestic electronics at the instigation of the refuse collection organisation IJmond-Zaanstreek (AIJZ) and Reinunie. This pilot project aimed at investigating the willingness of customers and retailers to co-operate in a collection system based on handing in used consumer electronics at local retailers, as well as the short-term effectiveness of such a system and the continuance in the long run.

In the remainder of this Section, an overview of the set-up and the main results and conclusions associated with this project (henceforth referred to as the RCS-project) are presented, based on the report by the consultancy firm that was hired to co-ordinate and support the execution of the project [Bureau Milieu & Werk, 2000].

Set-up of the RCS-project

At 14 retailers in the shopping centre of Heemskerk mini containers (120 litres) were placed where customers could leave behind their used 'small' domestic electronics. Two other collection points available to inhabitants of Heemskerk were a recycling store and the municipal waste yard.

The containers were emptied on call and reusable products were handed over to a recycling store, whereas the remaining products were transported to a recycling company for further processing.

The inhabitants of Heemskerk were informed about the pilot project by means of a letter and a number of articles and editorials in local and regional newspapers.

At the moment of handing over used products customers could fill in a form to participate in a lottery.

Within the framework of the RCS-project some specific additional research efforts were carried out, such as:

- a survey amongst customers,
- a survey amongst participating retailers, and,
- sorting analyses of household waste.

Results and conclusions from the RCS-project

About 29 % of all collected products in the RCS-project were suitable for product reuse purposes. This means that the following conclusion could be drawn: *Collection of 'small' domestic electronics by means of mini containers at retailers allows for product reuse of at least a portion of the collected products.*

Even though the RCS-project specifically aimed at collecting 'small' consumer electronics, the arsenal of collected products contained some other products categories as well, such as stereo equipment, heating equipment and 'big' white and brown goods.

The total amount of collected products in the RCS-project was 1,032 appliances with a total weight of 1,800 kilograms. The collection rate reported by the consultancy firm that was hired to co-ordinate and support the RCS-project was 35 % of the theoretical amount of disposed products as it was determined in this project. However, compared to the theoretical amount of disposed products as it was determined in Apparetour/Collection (Section 4.2) this percentage is slightly lower, i.e. ~ 31 %. The collection rate achieved in the RCS-project is the result of the combination of three collection routes: mini containers at retailers combined with a lottery, handing in at recycling store, and handing in at the municipal waste yard.

The combined collection routes applied in the RCS-project resulted in a collection rate that was slightly higher than the one applied in the Delft-project, which means that (in these two particular projects) a combination of a convenient bring system combined with a reward system and collection at a recycling store and the municipal waste yard scored slightly better than only applying a supermarket based bring/reward system. However, it is important to note that in the RCS-project, in contrast to the Delft-project, the communication efforts towards inhabitants focused on the environmental aspect of separate collection of consumer electronics instead of emphasising the enclosed lottery. Therefore, it is impossible to draw any further firm conclusions based on a comparison of these two projects.

A striking observation based on the RCS-project refers to the presence of 'small' consumer electronics in household waste that was analysed within the framework of this project. Even though a survey amongst inhabitants of Heemskerk revealed that customers were not 'aware' of the fact that they disposed of consumer electronics by means of the refuse bin for household waste, the sorting analyses proved this 'unawareness' not to be based on practice. Therefore, this project showed, in accordance with the analysis presented in Chapter 2 of this thesis and the results of other pilot projects, that *even though customers do not admit/acknowledge throwing consumer electronics in refuse bins/bags for regular household waste, sorting analyses show that this is 'common' behaviour. This observation also applies for situations in which alternative collection routes for the separate collection of consumer electronics are brought into being and communicated to these customers.*

The survey amongst inhabitants of Heemskerk revealed that 81 % was aware of the pilot project, even though 74 % had not handed in any products during the trial period. However, 80 % of the surveyed customers indicated that they would do so in the future, if the installed collection routes would be continued. Therefore, it could be concluded that *the means of communication applied in the RCS-project seem adequate to inform inhabitants of the collection points (of the bring system) available to them.*

The consultancy firm participating in this project calculated that applying the collection routes of the RCS-project results in costs amounting to 1.79 Dfl. (~ 0.80 Euro) per kilogram. Comparing these costs to the savings and additional revenues associated with separate collection of consumer electronics, as reported in the Delft-project (see Section 4.4), results in the following equation: 1.79 Dfl. – 0.236 Dfl. – 0.20 Dfl. = actual costs of 1.354 Dfl. per kilogram.

It should be noted at this point that the collection costs reported in the RCS-project are significantly higher than the collection costs reported in the Delft-project (1.79 Dfl. per kilogram compared to 6,000 Dfl. for 13.4 ton [De Straat Milieu-adviseurs B.V., 1999], which amounts to 0.45 Dfl. per kilogram), even though the applied schemes for collection are very similar.

4.6 Pilot project 5: Retailer Collection System-2 (2000)

Commissioned by the Ministry of VROM (Housing, Spatial Planning and the Environment), ARA (regional waste company Arnhem) carried out a pilot project in the region Arnhem to investigate the possibility of involving retailers in collecting 'small' consumer electronics.

In the remainder of this Section, an overview of the set-up and the main results and conclusions associated with this project (henceforth referred to as the RCS2-project) are presented, based on the report by ARA, the waste company that was hired to carry out the project [ARA Holding nv, 2000].

Set-up of the RCS2-project

The pilot project in Arnhem was composed of two specific parts:

1. Establishing a reference point by means of measurements (of collected amounts of 'small' consumer electronics at regular (existing) collection points) prior to the collection period, from May 1st 1999 up to October 31st 1999.
2. The collection period, from November 1st 1999 up to April 30th 2000.

A total of 32 retailers was approached to get involved in the RCS2-project and in the end 9 of them actually participated. The operating procedure to be followed during the collection period was appointed in written agreements with these retailers.

Two mini containers (240 litres) were placed at each of these stores. One of them actually in the store and one of them in a storage room, which acted as a so-called "substitute container." The latter was done in order to make certain that at least one collection point could be available in the store at all time.

The full containers were collected by ARA and transported to a Regional Storage Station. After conclusion of the RCS2-project the containers remained at the retailers for another month in order to enable them to seek alternative collection resources from the NVMP.

To inform the inhabitants of Arnhem about the project, a number of communication means were applied:

- press releases (prior to, during and after the project)
- advertisements in local magazines (prior to, during and after the project)
- leaflets at the participating retailers
- stickers on the mini containers at the retailers
- the ARA service telephone number

This communication campaign was set up in such a way that the central message joined with the communication by the NVMP and as such, the information provided in virtue of the RCS2-project comprised more than just the details about this particular project. Among other things, it also contained information about the regular collection points for consumer

electronics (municipal waste yard and handing in at retailers on grounds of the "old for new" regulation stipulated in the Disposal of white and brown goods Decree).

Results and conclusions from the RCS2-project

The enrolment of sufficient retailers to participate in the project proofed to be quite difficult, because most of them deemed the required space (for the container) and labour requirements too demanding. Another remarkable fact of this stage of the project was that a number of retailers indicated that they needed to consult with their head office before being able to make a decision about participating in the project. Sometimes this resulted in stimulation to participate by virtue of one's office, but in other cases head office clearly indicated that participation was undesirable. Therefore, the experiences within the RCS2-project result in the following conclusion: *The participation of retailers in a retailer based collection system for 'small' consumer electronics is not obvious in all circumstances: space and labour requirements can result in objections and holding companies seem to be divided about the desirability to let their retailers participate in such a collection scheme.*

The mini containers applied in the RCS2-project and the placement of these containers at retailers resulted in a very low level of contamination of the collected consumer electronics.

A striking result of the RCS2-project, especially in light of the enrolment difficulties described above, was the apparent contentment of the participating retailers with the collection scheme. All participating retailers indicated to be satisfied with the course of the project and declared themselves willing to continue with this collection scheme after the conclusion of the project. Therefore, based on this positive feedback, the feasibility of continuing or even expanding the project was assessed. This resulted in some very salient reactions by involved parties. The nationwide branch organisation for consumer electronics retailers indicated that it deemed an expansion of collection schemes involving retailers as undesirable and indicated that it wanted to restrict itself to the execution of the "old for new" regulation as laid down in the Disposal of white and brown goods Decree (see Chapter 2 of this thesis). Similarly, the NVMP deemed a second collection route, besides the current NVMP based "old for new" system, as undesirable. These observations are not only remarkable, they pose a very serious problem for any collection rate enhancing measure developed in this thesis beyond the existing NVMP system. Therefore, this ascertainment certainly deserves a more rigorous analysis. The final Section of this Chapter contains a first inception to such an analysis and this analysis is continued in Chapters 7 and 8.

The total amount of collected products in the RCS2-project was 14,737 appliances and the collection rate reported by ARA was 40 % of the theoretical amount of disposed products as it was determined in this project (based on [CREM, 1999]). However, compared to the theoretical amount of disposed products as it was determined in Apparetour/Collection (Section 4.2) this percentage would be somewhat lower, i.e. ~ 31 %. The collection rate achieved in the RCS2-project is the result of the combination of five collection routes: mini containers at retailers, handing in at the Regional Storage Station, by means of the chemical waste collection vehicle, curbside collection on call (intended for 'big' appliances), and handing in at two municipal waste yards. Therefore, it can be concluded that *the combined collection routes applied in the RCS2-project resulted in a collection rate that was similar*

to the collection routes applied in the Delft-project and the RCS-project: more collection routes do not necessarily result in higher collection rates.

After conclusion of the RCS2-project, it was decided not to continue the retailer based collection scheme. In the report by ARA, the reason behind this decision was described as "low zest among the retailers." However, this observation seems rather paradoxical in light of the observation described earlier in the report that all participating retailers indicated to be satisfied with the course of the project and declared themselves willing to continue with this collection scheme after the conclusion of the project. The reason for this inconsistency in the official report about the RCS2-project remains indefinite. However, the prominent and unambiguous discussion about the resistance of the NVMP and the nationwide branch organisation for consumer electronics retailers towards a continuation and/or expansion of this project could form intimation for an explanation (based on politics).

4.7 Three pilot projects supported by the NVMP (2001/2002)

In 2001 and 2002 the NVMP initiated and supported three pilot projects dedicated to the collection of 'small' consumer electronics. This Section describes the set-up and (preliminary) results of those projects, based on the report by the NVMP [PriceWaterhouseCoopers, 2001] and some additional (numerical) information provided by the NVMP and participating municipalities.

Before addressing the separate projects, it is important to note that the NVMP unequivocally states in its report on the results of those projects that "an important reference point for these initiatives is that the NVMP, based on the Disposal of white and brown goods Decree, is not primarily responsible for the collection of consumer electronics at consumers" [PriceWaterhouseCoopers, 2001]. The reason for including this statement in a report on projects dedicated to this issue, and initiated and supported by the NVMP, is not reflected. However, it could be argued that the NVMP considered it important to hint indirectly that these projects had a 'without obligations'-character and should be adjudged as such. Furthermore, it emphasises the fact that the NVMP is under no obligation to continue any novel collection scheme after the conclusion of these pilot projects, even if they turn out to be successful, or maybe even especially if they result in higher collection rates.

Retailer based (reward) collection system in Vorden

At 5 retailers (two supermarkets, a gift shop, a garden appliances shop and a drugstore) in the municipality Vorden mini containers were placed for the collection of 'small' consumer electronics. Consumers received a lottery ticket for each product that was handed in and the prizes consisted of two bicycles. The objective of the project was to surpass the result of the Delft-project with respect to the collected amount of 'small' consumer electronics.

In total, some 133 appliances per 1000 inhabitants were collected in two months, which amounts to a very high collection rate compared to the Delft-project (115 appliances per 1000 inhabitants in three months). In fact, the preliminary report [PriceWaterhouseCoopers, 2001] indicates that the collected amounts in Vorden are 8 times higher than the nationwide average. These results confirm the conclusion drawn from the Delft-project that *a*

convenient bring system combined with a reward system results in remarkably high collection rates for 'small' consumer electronics.

After conclusion of the pilot project, the retailer based collection system was continued, but without the reward system. Instead, customers received a small cash discount for purchases at the participating retailers. However, the collection rates for this adjusted collection scheme dropped dramatically compared to the pilot project. Therefore, the results of the pilot project in Vorden and the continuation with an adjusted collection scheme seem to indicate that *a reward system based on a lottery (with 'big' prizes) seems to result in higher collection rates than a reward system based on 'small' cash discounts.*

A final remarkable observation with respect to this pilot project is that, despite the apparent success, the NVMP has diminished its involvement with the continuation of this (adjusted) collection route and has indicated that "it is up to the municipalities (co-operating in this pilot project) to make a move" [PriceWaterhouseCoopers, 2001]. This observation appears to support the discussion about "an important reference point for these initiatives" depicted in the second paragraph of this Section.

Curbside collection system in North-Veluwe

In North-Veluwe (a region with 5 participating municipalities) a pilot project was initiated in 2001 incorporating various forms of curbside collection of 'small' consumer electronics. The collection of 'small' consumer electronics was combined with collection activities by charitable organizations, the 'small' chemical waste vehicle, local glass and paper collectors and a recycling store.

Unfortunately, detailed data about this pilot project are not (yet) available. However, the preliminary reporting by the NVMP [PriceWaterhouseCoopers, 2001] and additional information provided by B. Vonkeman (managing director of the NVMP) give rise to a few preliminary, but interesting, conclusions and observations.

One of the participating municipalities, Putten, scored significantly better with respect to achieved collection rates than the four other municipalities. What distinguishes Putten from the others is that in Putten the regular household waste collection is coupled with a so-called "diftar-system." This system boils down to a system of invoicing inhabitants of the municipality for household waste collection activities based on the amount of waste they offer to the collection service. In other words, this system encourages customers to hand in specific waste categories by means of separate collection routes for these products, because that (behaviour) results in lower costs for regular household waste collection services being charged to them by the municipality. The observation that Putten scores significantly better than the other participating municipalities in the pilot project seems to form an indication for the following (preliminary) conclusion: *Combining separate collection routes, such as curbside collection, for 'small' consumer electronics with a weight-based charging system for regular household waste collection services could enhance the (achievable) collection rates for 'small' consumer electronics.*

Furthermore, the first results of this pilot project seem to indicate that combining curbside collection of 'small' consumer electronics with the collection activities by charitable organisations and local glass and paper collectors results in higher amounts of collected

'small' consumer electronics than the combination with collection activities by either the 'small' chemical waste vehicle, or a recycling store.

Finally, a remarkable statement by B. Vonkeman (managing director of the NVMP) with respect to this project deserves mentioning here. According to Mr. Vonkeman, a decisive reason for the NVMP to discontinue their involvement with this project was the enormous amount of collected 'small' consumer electronics (and the fact that they were not sufficiently prepared to deal with such amounts at that point in time)! In other words, in this particular situation high collection rates (a high success rate of the pilot project) resulted in the NVMP discontinuing their support, which seems at least somewhat peculiar. However, once again, this observation appears to support the discussion about "an important reference point for these initiatives" depicted in the second paragraph of this Section.

Elementary school based collection system in three regions.

In October 2001, the NVMP started a pilot project dedicated to the collection of 'small' consumer electronics at elementary schools. In three separate regions and in three separate months, scholars could hand in the appliances at their school and followed special lessons on the subject matter of collection and recycling of consumer electronics. This collection route was combined with a school based reward system. If a school handed in more than one appliance per scholar it received a computer from the NVMP.

This pilot project resulted in the collection of some 250,000 appliances, about one third of the total amount of 'small' consumer electronics in the Netherlands per year. Therefore, the following conclusion seems fully justified: *A school based collection system, combined with a school based reward system, results in a remarkably high amount of collected 'small' consumer electronics.*

With respect to the (successful) collection route applied in this pilot project, the following two observations deserve attention at this point:

1. This pilot project provides an additional and convenient way of handing in used consumer electronics to a specific group of people (parents of scholars), but is not available to all consumers. Therefore, this collection route boils down to a convenient collection system for only a limited portion of the population.
2. The collection results of this pilot project indicate that if this collection scheme is not repeated, for instance on a yearly basis, this would imply a big 'missed opportunity.'

Regarding the latter observation, it is (again) striking that the NVMP has indicated that it is certainly not a given yet that this collection scheme will be repeated (in this form).

4.8 Discussion and preliminary conclusions

The cases presented in this Chapter give cause to some optimism with respect to the feasibility and impact of collection rate enhancing measures in general. The descriptions of the set-up and results of pilot projects pertaining to the collection of 'small' consumer electronics have revealed some successes in this area in recent years (compared to 'normal'

collection rates for ‘small’ consumer electronics, as reported in Chapter 2 of this thesis). Based on all the foregoing, Table 4.4 summarises the relative effectiveness (with respect to enhancing the collection rates of ‘small’ consumer electronics) of specific measures that were applied in the various pilot projects:

applied collection rate enhancing measures	*effect on (enhancing) collection rates*	*additional remarks*
parallel collection routes, but no curbside collection	+	collection rates for ‘small’ appliances still low
parallel collection routes, including curbside collection	++	collection rates for ‘small’ appliances can be enhanced by dedicated door-to-door collection
street containers	+	appliances get damaged and contaminated
collection points at supermarkets, combined with lottery based reward system	+++	
collection points at retailers, combined with lottery based reward system	+++	retailers seem reluctant to co-operate
parallel collection routes, including collection points at retailers	+++	nationwide branch organisation for retailers objected to continuation
collection points at retailers, combined with cash discount reward system	++	significant drop in collection rates after switch from ‘lottery’ to cash discounts
curbside collection	++	
curbside collection, combined with weight-based charging system	+++	
school-based collection, combined with school-based reward system	+++	available for a limited time frame and to only a limited portion of consumers

Table 4.4: Relative effectiveness of the various measures applied in pilot projects (+ represents the least effective measures, +++ represents the most effective measures)

Based on the results and findings presented in this Chapter, the following general conclusions seem justified:

- Enhancing the number of equivalent collection routes available to consumers and enhancing the service provided to those consumers (for instance, curbside collection instead of bring systems) usually results in (somewhat) higher collection rates.
- Merely applying advertisements and articles in local newspapers/magazines as a means to communicate with consumers about the collection routes available to them seems inadequate. The results of the pilot projects indicate that this approach needs to be supplemented by additional publicity campaigns and/or direct mail, such as a personal letter.
- As a rule, collection rate enhancing measures, specifically for 'small' consumer electronics, need to embrace a 'persuasive' element to stand a chance to change the custom behaviour of consumers to dispose of 'small' consumer electronics by means of the refuse bag/bin; the availability in itself of separate collection routes for 'small' consumer electronics is insufficient to influence the behaviour of the majority of consumers.
- The collection rate enhancing measures and communication means applied in the pilot projects described in this Chapter seem inadequate to influence the inclination of consumers to 'underestimate' the number of 'small' consumer electronics they dispose of by means of the refuse bag/bin.
- Street based containers seem inadequate to (significantly) enhance collection rates for 'small' consumer electronics and significantly reduce the opportunities for product reuse compared to collection routes applying supermarket and retailer based mini containers.
- Improving the convenience (for consumers) of collection routes by situating collection points at supermarkets or retailers (frequented by those consumers) seems to significantly enhance collection rates.
- Combining a collection route with a reward system (rewarding customers, or scholars of a school for handing in 'small' consumer electronics) seems to significantly enhance collection rates.
- A reward system based on a lottery (chance to win 'big' prizes) seems to have a higher collection rate enhancing effect than a reward system based on 'small' cash discounts/refunds.
- The effect of collection rate enhancing measures (for 'small' consumer electronics) is amplified by combining these measures with a weight-based charging system for regular household waste collection services.

The conclusions based on the pilot projects discussed in this Chapter and listed above could serve as 'valuable lessons' for the generation of design alternatives for collection rate enhancing measures in Chapter 6. However, it is important to note at this point that these lessons are based on a limited number of (isolated and, therefore, dissimilar) pilot projects and, what's more, lack any exemplification founded on (behavioural) theory. In other words, up to this point the value of these lessons for the design process presented in this thesis remains indefinite for the lack of indications about any justifiable generalisations of the effects/successes of specific measures. Therefore, the next Chapter addresses this issue

by presenting a review of available literature/theory in this area and consequent implications for designing collection rate enhancing measures.

Another important observation based on the exposé presented in this Chapter refers to the feasibility of specific collection rate enhancing measures in practice. As indicated in previous Sections, the willingness of (branch organisations of) retailers, municipalities, and even the NVMP to participate in and/or contribute to specific collection schemes seems at least uncertain (in particular circumstances). A striking illustration of this conclusion forms the establishment of the fact that so far none of the pilot projects presented in this Chapter, despite the apparent successful outcome of some, has resulted in any long-term nationwide prolongation or multiplication. This issue is addressed in more detail in Chapters 7 and 8 of this thesis, as it is directly related to the feasibility of any design alternative generated in Chapter 6.

Chapter 5

Enhancing collection rates for 'small' consumer electronics

Deriving theoretical perspectives from literature

and reference points for the design process

5.1 Introduction

In his thesis on social structural and social psychological factors affecting household-level environmental decision-making, Yangsoo states that "environmental problems will not be solved merely through technical process(es) and environmentally compatible products" [Yangsoo, 1999]. In fact, to substantiate this claim he includes the following citation from the work by Maloney and Ward [1973] on solving ecological problems: "Ultimately, the solution for environmental problems lies with the sciences that deal with changing human behaviour."

The purpose of this thesis is neither to validate or invalidate such statements, nor to engage in any generic discussion regarding the most 'appropriate' method of approach in dealing with environmental problems. However, based on the analysis presented in Chapters 1 to 3, it was concluded that making a maximum contribution to the attainment of the overall objective of the grouping of projects aiming at contributing to closing the life cycle of consumer electronics in the Netherlands is best served by focussing this thesis on the collection stage of the Product Recovery Network for 'small' consumer electronics. The latter implies that this thesis needs to address the fine-tuning of the junction between the consumers that set free used 'small' consumer electronics and the Product Recovery Network that absorbs and processes these products. In other words, this thesis focuses on a design effort to develop appropriate measures to enhance collection rates for 'small' consumer electronics and this approach eventuates in the necessity to address consumer behaviour and appropriate means to influence this behaviour. Ultimately, the analysis presented in this thesis results in specific recommendations with respect to adjusting the current collection schemes for 'small' consumer electronics in order to incorporate the collection rate enhancing measures that are generated, and such recommendations require "an insight into how consumers will respond to the scheme and how they will react to any management interventions that are designed to promote or sustain its performance" [Tucker et al., 1998]. More specifically, the design of successful collection rate enhancing measures requires more insight into what exactly is required of those measures to be successful; which elements need to be incorporated in such measures to be able to influence the behaviour of consumers in the desired direction. For the particular topic of this thesis this amounts to gaining more insight into the elements that need to be included in collection rate enhancing measures to discourage the disposal (by consumers) of 'small' consumer electronics by means of the refuse bag/bin and to promote the disposal by means of dedicated separate collection routes.

The previous Chapter (4) was dedicated to a description of a number of pilot projects dedicated to the collection of 'small' consumer electronics and resulted in establishing some 'valuable lessons' for the generation of design alternatives for collection rate enhancing measures in Chapter 6. However, these 'lessons' are based on non-scientific observations from a limited number of pilot projects and, what's more, lack any exemplification founded on (behavioural) theory. As was mentioned in Section 4.8, up to this point the value of these 'lessons' for the design process presented in this thesis remains indefinite for the lack of indications about any justifiable generalisations of the effects/successes of specific measures.

Based on all the above, it can be concluded that the generation of design alternatives in Chapter 6 would benefit a lot from establishing theoretical perspectives from the "sciences that deal with changing human behaviour" [Maloney and Ward, 1973] that are of relevance to collection rate enhancing measures and that explain (or possibly refute) the 'lessons' derived in the previous Chapter. Therefore, this Chapter presents an overview of relevant literature in this area and tries to establish relevant empirical findings (from research dedicated to this topic) and theoretical reference points that could serve as underpinning for an assessment of the adequacy and the chance to be successful of any specific collection rate enhancing measure and subsequent adjustments in current collection schemes. More specifically, this Chapter aims at establishing the "essential aspects that must be incorporated" [Cross, 1994] in collection rate enhancing measures to actually influence consumer behaviour, that determines these collection rates, in the desired direction (~ appropriate disposal behaviour).

The next Section commences this overview by briefly addressing some well-known general theories of human behaviour, that have served as a basis for understanding and predicting human behaviour in a number of research efforts. Section 5.3 focuses on research efforts and publications specifically dedicated to 'disposal behaviour' of consumers and establishes that "empirical observations, however, reveal more complex dependencies" [Tucker et al., 1998] than can be explained by means of those general theories of human behaviour. This discussion is followed by the introduction of the Triad model [Poiesz, 1999] that could possibly serve as a generic theoretical framework (suitable for supporting the design effort presented in this thesis), incorporating the findings presented in Section 5.3 and offering the opportunity for deriving the "essential aspects" mentioned above.

Consequently, the Triad model is applied in Section 5.5 of this Chapter in an attempt to provide an exemplification founded on (behavioural) theory of the 'lessons' learned from the pilot projects presented in Chapter 4. Subsequently, the model is also applied in the final Section of this Chapter in order to compare these 'lessons' and other relevant theoretical perspectives (as they are determined in this Chapter) with the current situation with respect to 'small' consumer electronics in the Netherlands. That means that the Triad analysis presented in Section 5.6 thereby finalises the *analysis* stage of the design effort presented in this thesis and establishes the point of departure for the next stage, i.e. the *synthesis* stage (Chapter 6).

5.2 Well-known general theories on human behaviour

For most (recent) theories on human behaviour, such as the famous theories of reasoned action [Fishbein, 1967; Fishbein & Ajzen, 1975; Ajzen and Fishbein, 1980] and planned behaviour [Ajzen, 1985; Ajzen & Madden, 1986; Ajzen, 1991] that are discussed farther down in this Section, the following two concepts serve as a reference point: expectations and value.

Expectancy-value models are founded on the central premise that the higher the expectancy that a specific behaviour will lead to a particular outcome and the higher the perceived value of that outcome, the more likely it is that that person will engage in that particular behaviour. A likely explanation for the appeal of this premise, resulting in the emergence of numerous theories about the relationship between expectations and behaviour [Pieters, 1989], is that it is "in accord with our commonsense thinking about motivated behaviour" [Weiner, 1992].

The application of this premise in theories on predicting/explaining behaviour generally involves the computation of the expected value or subjective expected utility (SEU), where the latter refers to the relevant probabilities and values as perceived by the decision maker, of each decision (behavioural) alternative more or less along the lines of the following (general) formula (Eq. 5.1):

$$SEU = \sum_{i=1}^{n} P_i * U_i \qquad (5.1)$$

In Equation 5.1, *SEU* refers to the subjective expected utility value of a specific decision (behavioural) alternative, P_i refers to the probability of outcome *i* if that particular decision (behavioural) alternative is performed, U_i refers to the utility (value) of outcome *i*, and *i=1...n* indicates the (number of) possible outcomes that are identified by the decision maker. Subsequently, *SEU* theory [Schoemaker, 1982] expects the decision (behavioural) alternative associated with the highest *SEU* value to be performed.

This point of departure has been employed by a number of authors. Some of these contributions (those that focus on environmentally relevant behaviour) are discussed in the next Section (5.3), while more elaborate discussions on this type of publications can be found in e.g. [Schoemaker, 1982], [Fischhoff et al., 1982], [Feather, 1982], [Van Raaij, 1977], and [Weiner, 1992].

One conclusion that can be drawn from all literature dedicated to this topic is that many "theorists seem to agree that expectancy-value models do not always provide a description of the actual decision processes individuals engage in" [Pieters, 1989]. The two basic arguments underlying this criticism are:

1. It is unreasonable to assume that people actually compute probabilities and values, multiply them and subsequently base their choice (of engaging in a specific behaviour) on the resulting numerical scores. Such a decision process amounts to "far too taxing and complex a process" [Mitchell, 1982].

2. The applied decision rule in *SEU* theory is so robust that it may predict actual decisions pretty well, even though this decision was reached by means of a completely different decision rule [Anderson & Shanteau, 1977].

However, despite these critical comments, the expectancy-value approach is still very popular [Pieters, 1989] and it actually forms the foundation of the two most famous and influential theories on human behaviour (the theories of reasoned action and planned behaviour of Ajzen & Fishbein) up to date by virtue of the attitude model of Fishbein [1963, 1967]. This model and subsequent reformulations by Ajzen & Fishbein [1975] form the core of "another line of motivation research (...) on the relationship between attitudes and behaviour" [Poiesz, 1995].

Literature reveals a number of alternative ways of defining attitudes, but Petty & Cacioppo [1981] state that in the end "there is widespread agreement (...) that the term attitude should be used to refer to a general and enduring positive or negative feeling about some person, object or issue."

In his attitude model, Fishbein [1963, 1967] applies a more formal definition by means of the following equation (Eq. 5.2):

$$A_{act} = \sum_{i=1}^{n} (b_i * e_i) \qquad (5.2)$$

In this formal definition of attitudes, A_{act} stands for the attitude towards a particular act, b_i refers to the belief that that act is associated with consequence i, e_i refers to the evaluation of consequence i, and n is the number of beliefs associated with that act. Along with Fishbein, a number of authors have tried to apply the attitude concept to predict behaviour, but simultaneously a number of authors have investigated the consistency between attitudes and behaviour [Pieters, 1989] and the empirical foundations of basing the attitude concept on an expectancy-value approach [Van Meegeren, 1997]. These investigations have cast doubt on the accuracy of Fishbein's attitude model [Ajzen, 1991][1] and especially the general assumption that attitudes comprise a valid basis for predicting behaviour. Some noteworthy comments with respect to the latter can be found in [Wicker, 1969], [Deutscher, 1966] and especially [McGuire, 1986], who states overtly that "the failure to find attitude-behaviour consistency is one of the scandals of social psychology."

From all this, it appears that attitudes (alone) are not able to predict behaviour very well. In an attempt to resolve these problems Ajzen & Fishbein introduced the theory of reasoned action [Fishbein & Ajzen, 1975].

Besides attitude (by means of the attitude model of Fishbein, in which the focal point has shifted to the attitude towards the specific behaviour under investigation), the theory of

[1] As indicated by Van Meegeren [1997], Ajzen acknowledged the lack of empirical foundations of an expectancy-value approach to determining attitudes. However, Ajzen remained confident about his and Fishbein's approach and the importance of attitudes in predicting behaviour, ultimately resulting in the development of the theories of reasoned action and planned behaviour (that presuppose the validness of both aspects).

reasoned action (TRA) includes another predictor of behaviour, i.e. the influence of the so-called subjective norm (SN). This subjective norm refers to the beliefs with respect to the approval or disapproval of important persons (referents) in the social context of the person that is considering that particular behaviour. More formally, the subjective norm can be expressed by means of the following equation (Eq. 5.3):

$$SN = \sum_{i=1}^{n} (b_i * m_i) \tag{5.3}$$

In Equation 5.3, *SN* stands for the subjective norm, b_i refers to the belief concerning the (dis)approval of referent *i*, m_i refers to the motivation to comply with referent *i*, and *n* represents the number of referents considered. In other words, the subjective norm refers to "what is the opinion of person *i* about what I should do, and to what extent do I care about that opinion?" [Poiesz, 1995]

In addition to the inclusion of a second predictor of behaviour, the TRA presupposes that behavioural intentions (BI) are the direct antecedents of actual behaviour and perform a mediating role between attitudes and subjective norms on one side and actual behaviour on the other. Therefore, the TRA can be represented schematically as follows (Figure 5.1):

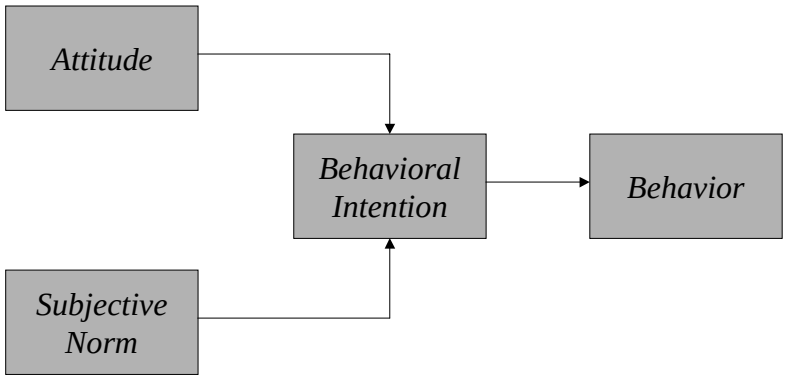


Figure 5.1: The theory of reasoned action [Fishbein & Ajzen, 1975]

However, in subsequent publications Ajzen himself noted that behavioural intentions stemming from an analysis based on the TRA only predict behaviour (well) if there are no

unforeseen barriers and if someone has full control over his/her own behaviour; if the behaviour is under "volitional control" [Poiesz, 1995].

This notion is closely related to the concept of self-efficacy that was introduced by Bandura [1977]. Bandura poses that the behaviour of individuals is influenced to a high degree by the extent of "conviction that one can successfully execute the behaviour (...)" [Bandura, 1977]. Other authors have adopted and tested similar assumptions (see e.g. [Warshaw, 1980] and [Hoevenagel et al., 1996]), and the overall conclusion arising from this line of research seems to be that 'desire' and 'capability' form important determinants for behaviour, especially with respect to environmental relevant actions [Van Meegeren, 1997].

In an attempt to account for the shortcomings of the TRA, through the lack of these important determinants of behaviour, Ajzen extended the TRA to include 'perceived behavioural control' as a behavioural determinant. Ajzen considered this to be such a fundamental adaptation of the original theory by him and Fishbein, that he decided that a "new name was required" [Van Meegeren, 1997]: the theory of planned behaviour (TOPB) [Ajzen, 1985; Ajzen & Madden, 1986]. The TOPB can be represented schematically as follows (Figure 5.2):

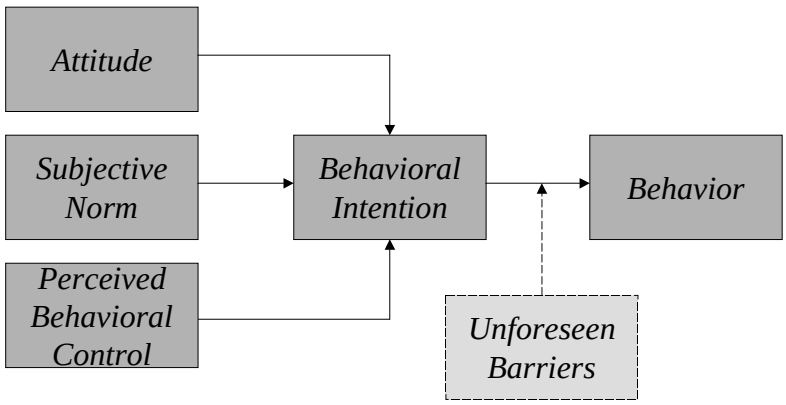


Figure 5.2: The theory of planned behaviour [Ajzen, 1985; Ajzen & Madden, 1986]

In the TOPB, the determinant 'perceived behavioural control' refers to the perceived chance of success or failure with respect to performing that particular behaviour. The more favourable the attitude and subjective norm, and the greater the 'perceived behavioural control,' the more likely it is that that person will have a high behavioural intention to

perform that particular behaviour; therefore, the more likely he/she is to perform the behaviour.

Despite the fact that the TRA and the TOPB have been applied by a number of authors in (publications dedicated to) research on human behaviour, a possibly even higher number of authors have expressed critical comments and observations with respect to the 'completeness' and 'practical applicability ' of these theories.

With respect to 'completeness,' it is important to note that the TRA (ensuing from an attitude-model) and subsequently the TOPB (ensuing from the TRA) are typical examples of a so-called "continuous search for variables that can be added to the variables already included in the theory in order to account for the remaining unexplained variance" [Poiesz, 1995]. This approach is a common and logical way to built theories, and literature dedicated to environmental behaviour certainly presents a number of examples of publications in line with this approach, many of them taking the TRA or the TOPB as a reference point "to discuss the role of other determinants of behaviour" [Pieters, 1989] and formulating "adjustments and supplements" [Van Meegeren, 1997] to these theories. Some of these publications are discussed in the next Section (5.3), as they present various interesting points of view in light of the topic under investigation in this thesis. The discussion in Section 5.3 presents a number of determinants of environmentally relevant behaviour (such as disposal behaviour) that are included in neither the TRA, nor the TOPB, but do however seem to play, based on empirical evidence, an important role in explaining and predicting this type of behaviour.

Simultaneously though, establishing this shortcoming of the TRA and the TOPB immediately eventuates in the establishment of the second main problem of these two theories and all subsequent adjustments and supplements to these theories; the (lack of) practical applicability.

The applicability problem of the above-mentioned arsenal of theories on human behaviour is related to several specific areas.

First of all, the way in which these theories have been built implies that (theoretically) there is no limit to the number of variables (that needs) to be included in an effort to accurately explain and predict behaviour. However, at some point "pragmatic boundaries are reached" [Poiesz, 1995]. As mentioned above, Section 5.3 reveals a number of determinants of (environmentally relevant) behaviour that, on closer inspection, should be included in any model that aims at explaining and predicting that behaviour. However, this presents any researcher or practitioner with a dead-end situation, in which a choice has to be made between employing a model that is considered 'incomplete' and the application of a model that proves 'impracticable.' Section 5.3 includes some obvious examples of this particular problem.

Secondly, the practical applicability issue is also closely related to the principle of compatibility, introduced by Fishbein & Ajzen [1977] themselves. This principle refers to the starting-point for any attitude-based behavioural model that the predictive function of attitudes "has been shown to increase with the level of correspondence between attitudes and behaviour, that is, corresponding levels of generality/specificity, at the same time, under similar conditions" [Poiesz, 1995]. As [Pieters, 1989] states, "if such a suggestion is

followed, the utility of the attitude concept may be limited considerable," and this casts serious doubt on the practical applicability of theories such as the TRA, the TOPB, and subsequent adjustments and supplements. Pieters describes this problem concisely, but vividly, as follows: "What is the value of the attitude concept, if the only attitudes that predict election results are those that are measured five minutes before the election?"

A third issue that refers directly to the applicability problems associated with the TRA, the TOPB, and subsequent theories arising from them deals with the type of behaviour that can be predicted by means of these theories. Fishbein's and Ajzen's theories deal with reasoned actions and planned behaviour, which means that these theories "offer explanations for behavioural choices that involve conscious deliberations" [Van Meegeren, 1997]. However, various authors in the field of environmentally related behaviour, especially disposal behaviour, have indicated that with respect to that type of behaviour 'habits' act as an important determinant of future behaviour. For instance, Boldero [1995] even concludes that past behaviour constitutes the only significant predictor of recycling behaviour. Therefore, many authors have concluded that the TRA and the TOPB are "insufficient to predict recycling" [Cheung et al., 1999]. Based on such conclusions, De Kruijk et al. [1993] state that "if behaviour has become customary, the role of behavioural intentions has diminished," thereby dismissing the practical applicability of theories such as the TRA and the TOPB in explaining and predicting disposal behaviour (~usually referred to as recycling behaviour in environmental literature).

A final problem with respect to the application of the TRA and the TOPB for predicting behaviour, especially disposal behaviour, concerns the fact that these theories "do not specifically address dynamic effects" [Poiesz, 1995]. Whereas these theories deal with limited time frames, ranging from determining the attitude towards a specific act to the act itself, disposal behaviour typically refers to repetitive behaviour and behavioural patterns in time. The TRA and the TOPB are linked with specific reasoned actions and planned behaviours at a particular point in time, and, as Poiesz [1995] states, "the question what happens subsequently to this behaviour (...) is a point that is usually not explicitly considered." This poses a problem for applying these theories in the field of environmentally responsible behavioural patterns, such as disposal behaviour, especially with respect to "breaking off environmentally damaging habits" [Van Meegeren, 1997].

5.3 Behavioural literature specifically dedicated to disposal behaviour

Even though (household) recycling and disposal behaviour could be considered relatively 'new' topics, in comparison with the general concept of human behaviour, already quite a number of authors have dedicated research efforts and subsequent publications to this field. Similar to research on human behaviour in other areas though, the TRA and the TOPB of Ajzen and others play a pivotal role in the method of approach that is adopted in a substantial portion of these publications. Some of them have addressed this issue by testing the applicability of the TRA/TOPB in this particular field; others have tried to formulate necessary (in their judgement) "adjustments and supplements" [Van Meegeren, 1997]. Furthermore, some publications give an account of attempts at 'merging' the TRA and the TOPB with other relevant theories and concepts. Simultaneously though, a few authors explore the applicability of alternative theories on human behaviour, whereas others investigate the importance of specific determinants of disposal behaviour that are not

associated with any general theory on human behaviour at all. Finally, some authors have specifically addressed the effectiveness of interventions that aim at changing specific disposal behaviour of consumers (e.g. collection rate enhancing measures).

This Section presents a bird's-eye view review of literature in this field. This is brought about by means of discussing a choice collection of publications, containing examples of each of the categories mentioned above. This discussion is not aspiring to completeness nor forms a review of all environmentally relevant behavioural literature in its entirety. In fact, literature in this field still comprises a number of discrepancies and obscurities. Lindsay & Stratham [1997] indicate that "many (...) studies are exploratory in nature" and underpin this statement, among other things, by referring to Thogerson's conclusion [1996] that "the research on the cognitive antecedents to recycling is characterised by single applications of general or ad hoc models." Resolving these problems certainly lies beyond the scope of this thesis, if that is in fact at all possible with respect to a topic as 'intangible' and as receptive to 'personal preferences' as (the determinants of) human behaviour. However, it does establish a cross-section of relevant theoretical perspectives and empirical findings with respect to the applicability of these 'general' theories on human behaviour in the field of disposal behaviour and illustrates the aspects that need to be addressed in designing measures that aim at influencing this behaviour.

5.3.1 Testing the applicability and completeness of the TRA/TOPB

Articles by, among others, Bagozzi [1992], and, Bagozzi, Yi and Baumgarter [1990] have indicated that the TRA might be lacking a crucial variable. They claim that 'effort' could prove to play a crucial role in predicting behaviour by acting as a moderator of the attitude-behaviour relationship that is modelled by the TRA. "Effort" was defined by Bagozzi et al. [1990] as "the degree of difficulty in executing the behaviour" and they claim that this degree of difficulty is directly related to the "impediments to performance of the behaviour."

Ajzen [1991] has addressed this issue by incorporating 'perceived control' in his TOPB, as was explained in the previous Section. In the TOPB, the perception of the amount of 'effort' that is needed to execute a specific behaviour will have an effect on the behavioural intention by addressing it as one of the determinants of 'perceived control.' However, some authors have since indicated that 'effort' should not only be considered by means of 'perceived control,' but rather as a direct moderator of "the relationship between attitudes and behaviour, regardless of behavioural intentions" [Schultz & Oskamp, 1996].

In their research effort dedicated to this topic, Schultz & Oskamp [1996] designed three studies to "examine the role of effort in the link between attitudes and behaviour, and to test the possibility that effort can reconcile the disparate research findings on the relationship between environmental concern and pro-environmental behaviours." The latter refers to the fact that research dedicated to the relationship between pro-environmental concern and pro-environmental behaviour has reported rather contradictory results (see e.g. [Schultz et al., 1995] and various other publications mentioned in the remainder of this Section).

From their research, Schultz & Oskamp [1996] concluded that, even though some authors have suggested that general pro-environmental concern lacks predictive power with respect

to conservation behaviour (e.g. [Vinning & Ebreo, 1992]), "general attitudes can directly predict behaviour in certain (!) situations." Simultaneously though, they found that this rule does not apply to situations in which the amount of effort required to engage in pro-environmental behaviour was relatively low, or when incentives were added. In other words, "when the amount of effort required to recycle is high, only people with strong pro-environmental attitudes are likely to do so. When the amount of effort required is low, however, a small or moderate environmental concern may provide enough impetus to produce the behaviour" [Schultz & Oskamp, 1996]. The latter also applies to incentives; people with relatively weak pro-environmental attitudes will react more pronounced to incentives, with increased recycling behaviours, than people with strong pro-environmental attitudes.

The work by Schultz & Oskamp demonstrates that in order to find an answer to the question "when attitudes predict behaviour" [Pieters, 1989], it is important to consider the moderating role of 'effort.' Therefore, (governmental) measures aiming at increasing recycling behaviour, in order to be successful, have to account for "the context in which the behaviour is taking place, and (...) the effort required for the behaviour is one aspect of that context" [Schultz & Oskamp, 1996].

Another study originally designed to test the TOPB in a recycling context was published by Lüdemann [1999]. However, in the end he dedicated most of his efforts to testing some hypotheses concerning 'thresholds' as an independent variable explaining environmental behaviour, particularly the choice between disposal of waste glass by means of a garbage can or a public recycling bin. The concept of thresholds, as Lüdemann applies it, refers to a specific application of SEU theory [Schoemaker, 1982] with respect to two disposal alternatives available to the population under investigation. Even though his analysis ran into some significant problems with respect to "the use and measurement of thresholds" [Lüdemann, 1999], his empirical data seem to support part of the conclusions by Schultz & Oskamp mentioned above. Overall, he concludes that garbage can users ('contra'-environmental behaviour) seem to attribute more effort (costs) and less benefits (utility) to pro-environmental behaviour. This eventuates in a situation in which efforts outshine environmental benefits and a threshold preventing these consumers to engage in recycling behaviour. These results seem to indicate that people with relatively weak pro-environmental attitudes are likely to let behavioural barriers, such as required effort, restrain them from pro-environmental behaviour. Persuading these people to engage in environmentally responsible disposal behaviour will therefore, at least, require addressing the concept of "effort required." A final striking observation referring to the work by Lüdemann concerns the concept of so-called "biospheric outcomes" [Lüdemann, 1999]. The empirical data resulting from his research efforts seem to indicate that the perception of consumers of actual environmental consequences has "no substantial effect on disposal behaviour" [Lüdemann, 1999]. This would therefore indicate that governmental efforts to stimulate environmentally responsible disposal behaviour by means of 'education' and 'giving information' in itself will not result in an increase of that behaviour.

A third publication dealing with a research effort that uses Ajzen's TOPB in a study dedicated to recycling behaviour is entitled "Re-examining the theory of planned behaviour in understanding wastepaper recycling" by Cheung et al. [1999]. Their study attempted to investigate the applicability of the TOPB in a wastepaper-recycling context. Cheung et al. refer to work by others (e.g. [Taylor & Todd, 1995] and [Vining & Ebreo, 1990], who

found that nuisance and economic motives that were specifically related to recycling could differentiate recyclers and non-recyclers!) for concluding that, even though the TOPB is a promising framework to predict (wastepaper) recycling behaviour, previous studies have not demonstrated "unequivocal results to support the entire model" [Cheung et al., 1999]. Besides the constructs included in the TOPB, Cheung et al. [1999] examined two additional sets of variables, i.e. environmental knowledge and past behaviour, and "the possible differences between the conceptualisation of perceived behavioural control as a uni-dimensional construct versus perceived behavioural control as a two-dimensional construct (i.e. perceived difficulty and perceived control)." From their examination of the behaviour of college students in Hong-Kong, in the end Cheung et al. concluded that the TOPB should be modified in several ways. First of all, they state that perceived behavioural control should be separated into perceived difficulty and perceived control as two "conceptually and empirically distinct constructs" [Cheung et al., 1999]. In fact, they found perceived difficulty to predict behavioural intentions and moderate the intention-behaviour link within the TOPB, whereas perceived control lacked any significant effect. The findings of Cheung et al. also support the notion that recycling behaviour is habitual in nature and "urge the inclusion of past behaviour when predicting recycling behaviour" [Cheung et al., 1999]. They even state that "consistent with Boldero's findings [1995], (...) for habitual acts such as recycling, past behaviour may play a dominant role in predicting subsequent performance of the behaviour" [Cheung et al., 1999]. Therefore, the work by Cheung et al. and others strongly suggests that for any intervention aiming at increasing environmentally responsible disposal behaviour to be successful it has to address the dynamic effects of behaviour and environmentally irresponsible behavioural patterns. This notion forms a confirmation of the hypothesis that promoting environmentally responsible behaviour will have to include some sort of "breaking off environmentally damaging habits" [Van Meegeren, 1997] (see Section 5.2).

5.3.2 Refinements and extensions of the TRA/TOPB

In recent years, a number of authors and institutions have defined 'new' models to assist them in predicting human behaviour, especially in the area of environmentally relevant behaviour. Most of these models are based on the TRA/TOPB, or at least are based on the same foundation (e.g. dealing with reasoned actions and incorporating the influence of attitudes; see Section 5.2), and consequently could be deemed as refinements and extensions of the TRA/TOPB. This Subsection discusses some examples of such 'new' models.

A very interesting example, in light of the scope of this thesis, refers to a conceptual model that was developed by the Sociaal Cultureel Planbureau (Social and Cultural Studies) in the Netherlands, commissioned by, among others, the Dutch Department of VROM (Housing, Spatial Planning and the Environment).

The behavioural model by the Sociaal Cultureel Planbureau (SCP) [Hoevenagel et al., 1996] assumes, pursuant to the TRA/TOPB, environmentally relevant behaviour of individuals is the result of a "reasoned choice process." However, it extends these models by including two determinants that are not systematically included in the TRA/TOPB, i.e. the 'supply' of behavioural alternatives and the behavioural 'capabilities' of the individual. The 'supply' of behavioural alternatives is defined as "the availability and quality of the

specific behavioural alternatives," while the 'capabilities' deal with "the means that are available to an individual to satisfy his/her needs" [Hoevenagel et al., 1996]. The SCP-model assumes that, given the supply and capabilities available to an individual, each person will base his/her choice for a specific behavioural alternative on individual 'motivations.' These motivations can be general of nature (general pro-environmental attitudes) or specifically related to a concrete behaviour, but the SCP fails to indicate how these different motivations can be distinguished and measured. Overall, the model that was developed and applied by the SCP can be summarised schematically as follows (Figure 5.3):

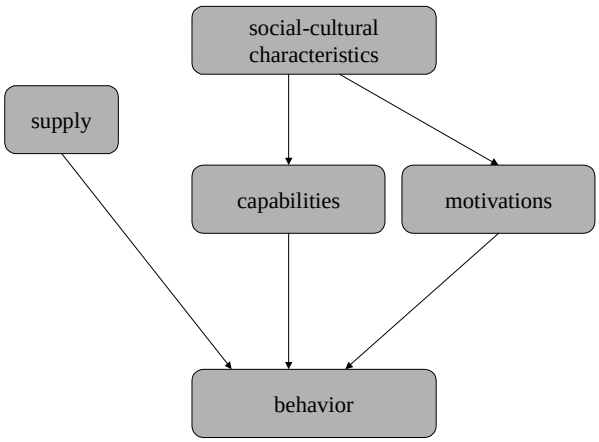


Figure 5.3: The conceptual model developed and applied by the SCP

Figure 5.3 reveals one very peculiar aspect of the behavioural model developed by the SCP; it assumes that 'capabilities' and 'motivations' are determined by the 'social-cultural characteristics' of the individual [Hoevenagel et al., 1996]. These 'social-cultural characteristics' contain elements that seem related to the 'subjective norm' concept of Fishbein & Ajzen [1975], however, they also contain aspects like: household type, age, occupation, ethnicity, religion, education and post materialism. The assumption that 'motivations' and 'capabilities' are determined by 'social-cultural characteristics' is not grounded, and what's more, the SCP even acknowledges that "this direct influence cannot be accounted for from a theoretical perspective" [Hoevenagel et al., 1996]. However, subsequent applications of the model still rest on this assumption based on "practical considerations" [Hoevenagel et al., 1996]. These considerations relate to three aspects: (1) the fact that motivations cannot be measured directly, (2) the availability (to the SCP) of a vast amount of data with respect to 'social-cultural characteristics', and finally, (3) the desire to predict future developments in environmentally relevant behaviour based on (available) predictions with respect to developments in 'social-cultural characteristics' of the Dutch population.

The above seems to indicate a clear weakness of the model developed by the SCP. This notion raises some question marks with respect to strategies applied by the Dutch government to promote environmentally responsible behaviour of its citizens, considering the fact that the Sociaal Cultureel Planbureau acts as one of its main advisory bodies.

Another author that has based his behavioural model (partly) on the TRA/TOPB is Peter Tucker, who has published a number of articles on the performance of local recycling programmes (e.g. [Tucker, 1999], [Tucker & Smith, 1999] and [Tucker et al., 2000]). Tucker claims that his model "merges and builds on concepts originally proposed in the theory of planned behaviour [Ajzen, 1985] with concepts proposed in the A-B-C model of Guagnano et al. [1995]" [Tucker et al., 1998]. Even though his publications up to now have not indicated yet that he has been able to validate his model as a whole, his ongoing research (based on a vast amount of empirical data) has already revealed some very interesting observations and support for specific elements of his approach. First of all, his work confirms the conclusion by other authors (e.g. [Oskamp et al., 1991]) that "pro-environmental attitudes rarely correlate with recycling behaviour" [Tucker et al., 1998]. Secondly, he emphasises the importance of barriers (effort) and claims that "minimising barriers, or perceived barriers" is important to "the successful marketing and management of any recycling scheme" [Tucker et al., 1998]. The latter is related to the application of the marketing approach in promoting recycling schemes, which is an approach that was promoted by Pieters [1991] as well, whose work is discussed in the next Subsection. Empirical data collected within the framework of his research efforts also confirm the notion that past behaviour is one of the strongest predictors of behaviour [Tucker et al., 2000]. Besides, one of his findings clearly indicates another possible problem with applying the (unrefined versions of the) TRA/TOPB in a recycling context, because he found that "if normative influence is occurring, its measurable effects are likely to be small" [Tucker, 1999]. In other words, Tucker's work casts doubt on the effect of (at least part of) the 'subjective norm' concept of the TRA/TOPB as one of the main determinants of human behaviour in recycling contexts. Overall though, Tucker's work can be characterised as mainly focussing on the effect of constraints (time, effort, storage space, inconvenience) on recycling behaviour and his research results seem to corroborate that encouraging recycling behaviour will at least involve addressing (~ reducing) the constraints involved with the current recycling scheme.

A final extension of the TRA/TOPB that is discussed in this Subsection was introduced by Van Meegeren [1997] in his thesis on communication and societal acceptance of environmental policies. Van Meegeren's work is a typical example of applying the approach of a "continuous search for variables that can be added to the variables already included in the theory in order to account for the remaining unexplained variance" [Poiesz, 1995]. He adopted the theories of Fishbein & Ajzen as a reference point and started adding variables based on a review of "adjustments and additions by various authors" [Van Meegeren, 1997]. Finally, this 'search' resulted in the following overall model (Figure 5.4), which Van Meegeren describes as a "state of affairs model" [Van Meegeren, 1997], and that could serve as a summary of the 'necessary' revisions and supplements to the TRA/TOPB that have been established in literature dedicated to this topic:

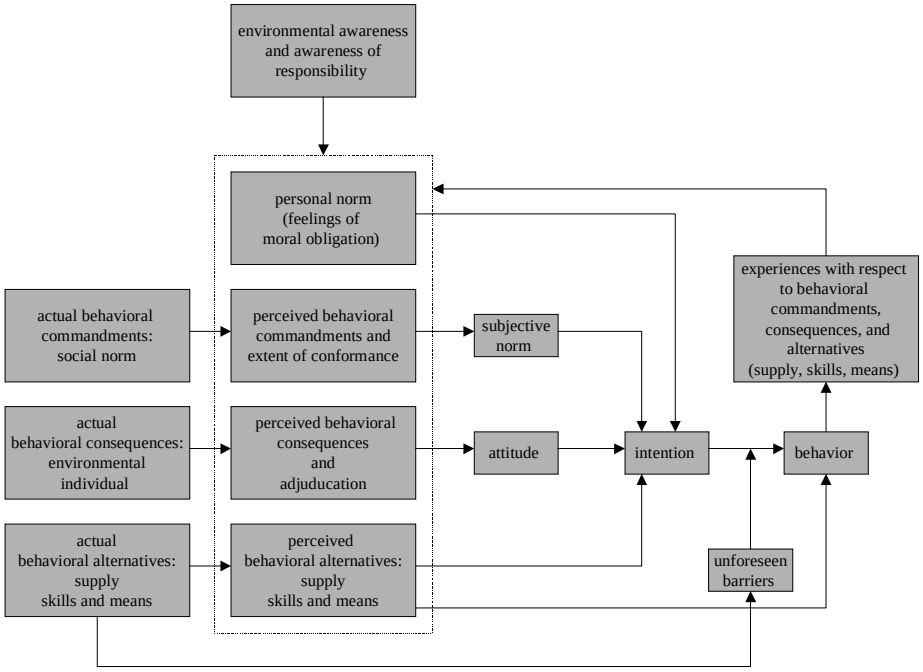


Figure 5.4: A model of determinants of reasoned environmental behaviour[2]

The remainder of his thesis is dedicated to the effectiveness of communication as an intervention by governmental institutions to encourage environmentally responsible behaviour by its citizens. Some of the most important conclusions that are reported by Van Meegeren are [Van Meegeren, 1997]:

- Education/communication can serve as an appropriate and effective intervention to encourage and promote environmentally responsible behaviour by consumers, if the reasons for not engaging in that behaviour are directly related to impediments with respect to the knowledge and capabilities of those consumers.
- Education/communication are unsuitable as a independent/autonomous intervention to encourage and promote environmentally responsible behaviour by consumers, if
    - the current behaviour is habitual in nature,
    - the desired behaviour is hindered by a lack of personal means (of the consumers) and collective facilities, and, if

[2] Following the example of Van Meegeren [1997], for the sake of convenience the mutual relations between attitude, subjective norm, personal norm and perceived behavioural alternatives have been omitted. In other words, the actual model of determinants would be even more elaborate and complex than the one displayed here. Van Meegeren's model thereby clearly illustrates the problems with respect to the 'practical applicability' of such a model.

- the desired behaviour requires consumers to invest (considerable amounts of) time, money, and effort.

These conclusions establish some very important points of reference with respect to an evaluation of current strategies applied by the Dutch government to encourage/promote the collection of 'small' consumer electronics. Therefore, this and related issues are discussed in more detail in Chapter 8 of this thesis.

At this point though, the overall model introduced by Van Meegeren offers some very interesting jumping-off points for the remainder of this Section, i.e. the role of individual consequences versus societal consequences, and moral costs and benefits.

5.3.3 The influence of social dilemmas and altruism

One of the most important aspects to take into account in explaining and predicting environmentally relevant behaviour has not been discussed in the review presented in this Section as of yet: the special character of environmental problems. The most characteristic feature of these problems can be best explained by means of the concept of social dilemmas. Social dilemmas can be defined as "situations in which a number of individuals depend upon each other and in which the individual interest (self-interest) can conflict with the collective interest (societal interest)" [Liebrand & Van Lange, 1989].

In an environmental context, social dilemmas refer to situations in which "it is easier, more profitable and more appealing for the individual to engage in environmentally irresponsible behaviour than environmentally responsible" [Wit, 1994]. In fact, environmental problems represent 'complex' social dilemmas, because of [Van Meegeren, 1997]:

- the large-scale character of most environmental problems,
- the fact that most environmental problems only become noticeable (visible) in the long run,
- the precariousness with respect to the gravity of a number of environmental problems, and,
- the spatial separation between causes and consequences of environmentally irresponsible behaviour.

Van Meegeren [1997] states, based on a review of available literature, that "considering the fact that most environmental problems can be characterised as complex social dilemmas, the choice for personal benefits at the expense of collective environmental damages seems obvious, despite the recognition of the importance of environmental problems." Van Meegeren [1997] claims that individuals are likely to ascribe more value to personal disadvantages with respect to time, money, and effort required, than the collective environmental disadvantages. Simultaneously, it is quite possible that individuals have little confidence in the willingness of others to engage in environmentally responsible behaviour, and therefore adjudge their own (possible) contribution as insignificant [Wit, 1994].

Van Meegeren [1997] suggests that solutions for environmental problems should therefore not focus on an appeal to those individuals for voluntary changes in behaviour for the

benefit of the environment, but rather on minimising the social dilemma, for instance by means of rewards and punishments that favour environmentally responsible behaviour and discourage the opposite. This notion has been investigated by a number of authors, especially by combining the TRA/TOPB with Schwartz's [1977] theory on altruistic behaviour. Altruistic behaviour refers to behaviour that benefits others (society) without resulting in rewards for the individual that is engaging in that behaviour. As such, environmentally responsible behaviour could be deemed a specific type of altruistic behaviour, because it usually involves contributing to solving environmental problems without receiving a (personal) reward for that behaviour.

According to Schwartz's theory, individuals that have to make a choice that has consequences for others, go through a process that involves the following four stages: (1) the perception of a need or problem, (2) activation of personal norms, (3) assessment, evaluation and reassessment of potential responses, and finally, (4) (in)action. Schwartz [1975] hypothesises that ascription of responsibility moderates the relationship between personal norms or attitudes and actual behaviour. In other words, if a person perceives a problem and assesses that he/she can contribute to the solution, and finally, feels responsible to contribute, he/she will engage in altruistic behaviour based on a favourable balance with respect to moral costs and benefits. The two central concepts in such a process are: 'awareness of consequences,' and 'ascription of responsibility' or more precisely 'responsibility acceptance or denial.'

Bratt [1999] published an article that focussed on the first of those two central concepts, combining a portion of the TRA/TOPB with a portion of Schwartz's theory on altruistic behaviour. As indicated by Bratt himself, "the most significant contribution by this study is that it questions the focus on awareness of consequences in predicting and motivating the recycling of waste" [Bratt, 1999]. In fact, Bratt concludes that campaigns meant to induce environmentally friendly behaviour should not concentrate on environmental uncertainty. The latter implies that communication efforts by governmental institutions dedicated to educating citizens about environmental consequences of specific behaviours could prove to be rather unsuccessful in stimulating environmentally responsible behaviour.

Yangsoo [1999] arrives at similar conclusions in his thesis and advocates focussing more on extrinsic incentives, particularly financial incentives, because such measures "could prove to be worthwhile in encouraging waste reduction behaviour."

Pieters' [1989] thesis on attitudes and behaviour in a source-separation program is a final example of an author that has dedicated his research efforts, among other things, to investigating the influence of moral costs and benefits, while applying the TRA/TOPB. He focuses on the second of the two central concepts of Schwartz's theory on altruistic behaviour by testing "the moderating effect of acceptance of responsibility in the context of the Reasoned Action theory" [Pieters, 1989]. The main results of his study (comparing participants and non-participants in a source-separation program) are that ascription of responsibility does not differ between participants and non-participants, and that attitudes, and thereby behaviour(al intentions), are mainly determined by perceived costs and benefits. His research results cast serious doubt on the influence of acceptance of responsibility on reasoned actions in a recycling context. In fact, he advances a similar conclusion to that of Yangsoo in claiming that "in predicting (...) behaviour the best fitting

models may prove to comprise less internal determinants and more external determinants of behaviour, i.e., those studied in operant conditioning theory" [Pieters, 1989].

The above examples illustrate the overall conclusion that most authors that have investigated (the influence of) social dilemmas and altruistic behaviour in a recycling context have found no evidence of a substantial influence of moral costs and benefits in explaining and predicting behaviour of (groups of) customers. In fact, their research usually corroborates the point of departure brought forward by Van Meegeren [1997] mentioned above.

5.3.4 Alternative models, specific determinants and the effectiveness of interventions

Lindsay & Stratham [1997] published an article on the application of a modified Health Belief Model (HBM) in predicting recycling behaviour. They underpin this approach by referring to two main problems that surface from their examination of literature on "ecological-related behaviour" [Lindsay & Stratham, 1997]: (1) the various behaviours that are a part of this domain do not result from the same antecedents, and, (2) "although a good deal of research has been conducted, much of the research examines the individual influences of a few variables without attempting to incorporate those variables into a larger theoretical framework" [Lindsay & Stratham, 1997].

Even though one might argue that the latter is a logical, and maybe even unavoidable, result of the first problem, Lindsay & Stratham try to address both these problems by "applying a modified theory common in the health literature and applying it to one sub domain of responsible environmental behaviour" [Lindsay & Stratham, 1997]. The latter part of the description, "applying it to one sub domain of responsible behaviour," seems to indicate a somewhat peculiar choice, because this method of approach results in the infeasibility of assessing the applicability of the HBM to other sub domains and thereby the generic applicability of this model in the whole domain of environmentally relevant behaviour of consumers.

However, the choice for applying the HBM in predicting recycling behaviour does mean that the findings presented in this article provide the opportunity of checking to see whether applying an alternative behavioural model (as against the TRA/TOPB based approaches) results in significantly different conclusions with respect to establishing the importance of specific determinants of recycling behaviour (as they have been reported in the previous Subsections). Lindsay & Stratham themselves indicate that "the most reliable finding in this investigation and in studies performed by other researchers is the role of difficulty, barriers, or personal convenience in recycling behaviour. The perception of difficulty in recycling inhibits individuals from actually performing this behaviour, despite the fact that most people believe that recycling is beneficial to the natural environment" [Lindsay & Stratham, 1997]. Furthermore, their findings confirm the fact that environmental problems stemming from insufficient recycling by consumers can be characterised as a 'complex' social dilemma [Van Meegeren, 1997], because consumers "have yet to experience symptoms of the negative consequence we are trying to prevent" [Lindsay & Stratham, 1997]. As such, the findings presented in this publication confirm the statements made in the previous Subsection indicating that encouraging environmentally responsible behaviour, such as recycling, involves minimising the social dilemma, for instance by means of rewards and

punishments that favour environmentally responsible behaviour and discourage the opposite.

In contrast to Stratham & Lindsay, a number of authors have investigated the importance of specific determinants in predicting recycling behaviour and the subsequent effectiveness of specific interventions to influence this behaviour without focussing on the need for an overall theoretical framework. In fact, some of them even argue that such an overall framework is infeasible, because "different personal characteristics and situational influences predict the different behaviours" [Oskamp et al., 1991].

Oskamp et al. [1998] investigated variables that might predict observed recycling in a community-wide residential curbside-recycling program. They found that "general environmental concern did not make a significant contribution to the prediction of participation in recycling programs," but "it did significantly relate to quantity per participation" [Oskamp et al., 1998]. In this particular recycling program, which could be characterised as a convenient curbside program, general environmental concern obviously was not the main determinant for participating or not participating. It only influenced the level of enthusiasm of participating of the ones willing to engage in recycling behaviour. Another conclusion put forward by Oskamp et al. was that "increasing residents' knowledge about the materials collected in the current program may lead to more collected material but may be ineffective at reducing contamination or increasing participation rates" [Oskamp et al., 1998]. Finally, Oskamp et al. found only very weak relationships between demographic variables and recycling behaviour, which confirms that the assumption made by the Sociaal Cultureel Planbureau (see Subsection 5.3.2) that 'motivations' and 'capabilities' are determined by 'social-cultural characteristics' and consequently influence recycling behaviour is not grounded [Hoevenagel et al., 1996].

In fact, as mentioned above, Oskamp is a clear example of an author that dismisses the value of general models in explaining and predicting behaviour and he states that "for policy purposes, the most useful studies are the ones that attempt to increase the level of recycling by using experimental interventions" [Oskamp, 1995]. In his article on "behaviour and policy" [Oskamp, 1995] in the area of resource conservation and recycling he summarises the findings for several types of interventions. With regard to monetary rewards he explains that these types of interventions "have been found to increase recycling behaviour," but it is important to note that "when the rewards were discontinued, the behaviour returned to previous baseline levels." This observation resembles the results of some of the pilot projects described in Chapter 4 of this thesis. Another successful intervention in short-term experimental campaigns has been "removing barriers," which confirms that the amount of effort required to engage in recycling behaviour constitutes a very important determinant of such behaviour. Again, this observation validates the findings presented in the previous Chapter of this thesis. Finally, another interesting conclusion put forward by Oskamp [1995] is that "goal setting" could prove to be a successful and feasible intervention if applied to neighbourhoods or schools. Obviously, this observation is in full accordance with the observed remarkably high collection rates achieved by means of the elementary school based collection system described in Section 4.7 of this thesis.

Another example of a publication that documents "the labours of researchers who specifically targeted recycling with behaviour change programs" was published by Porter et

al. [1995]. Their observations confirm the findings by Oskamp [1995] with respect to the effectiveness of interventions that focus on making recycling more convenient and easier, introducing goal setting techniques, and rewarding recycling behaviour. Regarding the latter, Porter et al. [1995] advance some very interesting findings. First of all, they conclude that individual and group rewards can significantly increase recycling, "but not as much as (...) lottery conditions" [Porter et al, 1995]. This observation clearly is in full accordance with the findings presented in Chapter 4 of this thesis, which describes the eye-catching results that were achieved with lottery based reward systems in pilot projects aiming at increasing the collection rates for 'small' consumer electronics in the Netherlands. The second important finding put forward by Porter et al. [1995] refers to the cost-effectiveness of lottery-based interventions. They report that "by gradually increasing the amount (...) necessary to receive a chance for reinforcement, the cost-effectiveness and potential for implementing larger scale lottery programs were increased without decreasing effectiveness" [Porter et al., 1995]. Finally, they establish that "employing rewards produced large increases in recycling, especially when lotteries were used to reward individuals as opposed to (...) rewarding recyclers with immediate, smaller rewards" [Porter et al, 1995]. This final conclusion supports the findings presented in the previous Chapter of this thesis, where the results of pilot projects in the Netherlands gave cause for similar (preliminary) conclusions with respect to the effectiveness of a lottery based reward system as against a reward system based on 'small' cash discounts.

The role of financial consequences associated with recycling behaviour has been at the centre of attention in many publications dedicated to investigating the effectiveness of interventions to increase recycling behaviour. For instance, Linderhof et al. [2001] published an empirical analysis of the effects of weight-based pricing in the collection of household waste, Fullerton & Kinnaman [1996] investigated household responses to pricing by the bag, and Jenkins et al. [1999] report on their analysis of unit pricing and recycling program attributes. Their findings are quite similar and confirm the conclusion presented in the previous Chapter of this thesis that combining separate collection routes for recyclables, such as curbside collection, with a weight-based charging system for regular household waste collection services could significantly enhance the (achievable) collection rates for recyclables. In fact, Fullerton & Kinnaman [1995] conclude that the optimal fee structure for such a collection scheme is a deposit-refund system: "a tax on all output combined with a rebate on proper disposal through either recycling or waste collection" [Linderhof et al., 2001]. However, all authors mentioned above come to the same conclusion with respect to another "attribute of recycling programs" [Jenkins et al., 1999]: in the end, "curbside recycling pickup increases the probability of recycling more than does unit pricing of garbage" [Fullerton & Kinnaman, 1996]. This conclusion once again confirms the obvious significance of barriers/effort as a determinant of recycling behaviour, as it has already been established in the course of this review.

5.3.5 Main conclusions from all the above and a stepping-stone for the remainder.

All the examples of publications dedicated to research efforts focussing on disposal behaviour of consumers presented in the previous Subsections contain specific illustrations of aspects that will need to be addressed in virtue of a design effort dedicated to developing collection rate enhancing measures for 'small' consumer electronics. Therefore, this

Subsection attempts to provide a stepping-stone for the remainder of this thesis by summarising the most relevant findings and establishing the main general conclusions.

The above has revealed that concepts like normative influence, pro-environmental attitudes and general environmental knowledge/concern constitute weak predictors of environmentally responsible behaviour, such as adequate disposal behaviour. The discussion with respect to moral costs and benefits, and Schwartz's theory on altruistic behaviour, uncovered the fact that environmentally responsible behaviour is usually directly linked with 'complex' social dilemmas. Unfortunately, the results from available literature seem to indicate that educating consumers about environmental consequences and appealing to a voluntary change in behaviour based on a sense of shared responsibility cannot resolve this dilemma.

Simultaneously, the review presented in this Section has revealed that some other specific aspects with respect to environmentally relevant behaviour do in fact make up strong predictors of this type of behaviour.

First and foremost, the concepts of barriers and effort required seem to be very closely related to the willingness of consumers to engage in environmentally responsible behaviour. In other words, the more convenient it is for an individual to engage in the 'desirable' behaviour, with respect to the amount of time, money and effort that needs to be invested to perform that behaviour, especially in comparison to the 'undesirable' behavioural alternative(s), the more likely that individual is to engage in that behaviour. Research with respect to the effectiveness of interventions to encourage 'desirable' behaviour has revealed that this aspect constitutes an important opportunity to influence and guide the behaviour of consumers in a more environmentally responsible direction. Incorporating actual reductions in the amount of time, money and effort that consumers have to invest in a specific behavioural option, and possibly increasing the barriers linked with 'undesirable' options, will play a pivotal role in the effectiveness of specific measures.

Secondly, the ratio between perceived costs and benefits forms another important predictor of this type of behaviour. This aspect constitutes another important opportunity to influence consumers' behavioural patterns. Actually influencing this ratio requires influencing the actual costs and benefits associated with specific behavioural options, for instance by means of reducing barriers and effort required (as discussed above), or by increasing associated benefits, i.e. rewarding 'desirable' behaviour. Research with respect to the effectiveness of interventions has revealed that financial rewards can play a very important role in increasing environmentally responsible behaviour by consumers. That same research seems to indicate that the best results can be achieved by applying lottery based reward systems instead of a reward system based on 'small' refunds. Furthermore, combining a reward system with a weight-based charging system for regular household waste services presents a promising approach in the specific field of recycling/disposal behaviour.

A final important observation with respect to influencing environmentally relevant behaviour refers to the habitual nature of many behavioural options in this field. Environmentally relevant behaviour, especially recurring behaviour such as disposal of household waste (including 'small' consumer electronics), often manifests itself in behavioural patterns that are based on an assessment of costs and benefits in the past. Therefore, influencing this type of behaviour not only requires interventions/measures to

alter the costs/benefits ratio linked with the various behavioural options available to consumers, simultaneously these interventions/measures need to 'grasp' the attention of these consumers and spur them on to a reassessment of this ratio. The latter illustrates the importance of focussing communication efforts on specific types of environmentally relevant behaviour and associated (short-term) costs and benefits for the consumers involved, instead of trying to educate these same consumers with respect to the (long-term) environmental consequences and their shared responsibility in resolving environmental problems.

5.4 Introducing the Triad model

The previous two Subsections have revealed a number of important observations for the remainder of the design effort presented in this thesis. In a nutshell, one could argue that available literature incorporates a number of relevant conclusions with respect to determinants of environmentally relevant behaviour such as disposal behaviour. However, the overall impression evoked by a review of existing publications, particularly for the field of recycling/disposal behaviour, is one of isolated research efforts and limited generalisation and translation in theoretical points of reference, which significantly complicates the application of these results in other/different settings. Simultaneously, research efforts that have explicitly addressed this issue by founding the analysis on a theoretical framework have predominantly reverted to employing general well-known theories on human behaviour such as the theory of reasoned action and the theory of planned behaviour of Ajzen and companions and applying the approach of a so-called "continuous search for variables that can be added to the variables already included in the theory in order to account for the remaining unexplained variance" [Poiesz, 1995]. However, the analysis presented in Subsection 5.2 (and some further illustrations of the points made there in Subsection 5.3) has revealed a number of difficulties and limitations with respect to the applicability of these general theories that will inevitably surface in applying them in an analysis (and subsequent design effort) dedicated to disposal behaviour.

In an effort to accommodate with the above limitations of available literature and to provide a framework that could serve as a basis to further the coherence of the various steps of the design effort presented in this thesis (and the effectiveness of the ultimate design), this Section introduces the Triad model [Poiesz, 1995/1999]. This model could possibly serve as a generic theoretical framework (suitable for supporting the design effort presented in this thesis) that can incorporate the findings presented in Section 5.3, while offering 'solutions' for the 'applicability' and 'completeness' issues raised in Section 5.2, thereby providing the possibility to derive practical implications. More specifically, it could serve as a means to establish all "essential aspects that must be incorporated" [Cross, 1994] in the collection rate enhancing measures that are developed in the remainder of this thesis (the required input for the first step of the Morphological Chart Method applied in the synthesis stage of the design process).

The Triad model is not a 'new' model in the sense that "it provides a totally unprecedented way of dealing with human behaviour," in fact, it is "strongly inspired by existing knowledge and empirical evidence already accumulated" [Poiesz, 1995]. Poiesz himself states that the model should be seen as an attempt to combine scientific research and

experiences from application (see e.g. [Vergeer, 2001] and [Van Eijk, 2002]) and that the Triad model should be treated as "an example of a generic theoretical framework which gives the opportunity to derive practical implications" [Poiesz, 1999]. Therefore, the analysis presented in this Section certainly is not intended to present a generic discussion regarding the most appropriate theory on human behaviour, or to suggest the superiority of the Triad model in comparison to other models and approaches. In fact, one of the possible drawbacks could be that the highly generic nature of the model, as an integrative meta-model, complicates operationalisation in specific circumstances. On the other hand, it does allow for the integration of existing (other) empirical findings and theoretical perspectives in an analysis by means of the Triad model, which could simultaneously enhance operationalisation. For a more detailed discussion with respect to the 'status' of the Triad model/analysis and other possible drawbacks/advantages, see [Poiesz, 1999]. In this thesis, the Triad model is introduced in this Section, and subsequently applied in the remainder, in the way Poiesz [1999] intended his model to be looked at and employed: as a simple and practical model that can be applied to explain, predict and influence behaviour, without ignoring or contradicting scientific findings (already available).

The main reasons for the choice to apply the Triad model in the analysis (and design effort) presented in this thesis can be summarised as follows (some of these aspect are illustrated in more detail in the next Section):

- The 'completeness' of the Triad model:
  The model covers a combination of (existing) theoretical perspectives and *logic*. It offers the opportunity to include all relevant determinants of human behaviour in the analysis, instead of focussing beforehand on only a limited portion of all determinants (as is done by a number of other psychological theories and models). In fact, as Poiesz [1999] states, "in comparison to other models, it makes high demands on measures that are aimed at influencing behaviour." As a result of the multiplicative nature of the Triad model, all conditions need to be satisfied for a specific measure to be deemed 'appropriate.' The choice for applying the Triad model in establishing the "essential aspects that must be incorporated" [Cross, 1994] in (design alternatives of) collection rate enhancing measures thereby promotes the development of measures that cover (and influence) all relevant determinants of disposal behaviour.
- The 'practical applicability' of the Triad model:
  Besides the limited number of variables that needs to be included, the model offers the opportunity to address behaviour that does not involve "conscious deliberations" [Van Meegeren, 1997], or that has "become customary" [De Kruijk, 1993]. In other words, a Triad analysis does not require controlling (or eliminating) the circumstances surrounding a particular behaviour (the principle of compatibility; see Section 5.2). In fact, it offers the opportunity to include these outside influences in the analysis. Those characteristics make the Triad model suitable for an analysis and design effort that specifically focus on (inappropriate) disposal behaviour with respect to 'small' consumer electronics; a type of behaviour that has become customary to many consumers and that takes place in their (private) homes.
- The emphasis on 'opportunity':
  The model explicitly addresses 'opportunity' as one of the three main determinants of behaviour, thereby complying with the importance (as established in the

previous Sections) of the concepts of barriers and effort required in explaining, predicting and influencing environmentally relevant behaviour, such as disposal behaviour.

- The dynamic character of the Triad model:
  As opposed to the majority of existing psychological models, the Triad model offers the opportunity to monitor (determinants of) behaviour in the course of time. As mentioned above, disposal behaviour usually "becomes customary" in the course of time and refers to repetitive behaviour and behavioural patterns in time. Therefore, the specific character of the topic under investigation in this thesis constitutes a final reason for applying the Triad model.

The remainder of this Section presents a discussion on the Triad model, with respect to the content and the points of departure, based on the work by Poiesz [1995, 1999]. Simultaneously, this discussion includes some further illustrations of how the Triad model can accommodate with the limitations (with respect to 'applicability' and 'completeness') of available literature, while incorporating the findings presented in previous Sections. In the remainder of this thesis, the Triad model is applied at various stages of the design effort, for example:

- To conclude the analysis stage (Sections 5.5 and 5.6) by re-examining the 'lessons' learned from the pilot projects presented in Chapter 4 and the situation with respect to the current Product Recovery Network for consumer electronics in the Netherlands, especially regarding the effect of current structures and regulations on the collection of 'small' consumer electronics.
- In the evaluation stage (Chapter 7), as one of the means to evaluate the (effectiveness of) specific design alternatives.

The Triad model: content and applicability

In Sections 5.2 and 5.3, it was established that the most common way of building theories on human behaviour, certainly with respect to environmentally relevant behaviour (as discussed in the previous Section), is to engage in a search for remaining determinants that can be added to the determinants of an existing model (usually a model based on the TRA/TOPB) to account for unexplained variance. Another approach is to focus on separate determinants, without applying an underlying model or theory. However, both of these approaches result in the emergence of serious problems with respect to practical applicability. Whereas the first approach is theoretically infinite, because establishing an overview of all possible determinants of all possible behaviours can be continued way beyond the boundaries of pragmatism, the latter always results in the unanswered question: "Did we take the most important determinants into account, and how can the remaining variance be explained?"

An alternative approach to building a theory on human behaviour would be to start off from a "pre-determined taxonomy of potential variables and select, after careful inclusion and exclusion of variables in this taxonomy, the variables and relationships relevant for behaviour explanation" [Poiesz, 1995]. The Triad model departs from such a system or taxonomy of determinants, instead of an *ad hoc* combination of variables that needs to be expanded or replenished, or deliberately focussing on only a limited portion of the determinants of human behaviour.

The Triad model assumes that behaviour will take place if three conditions are met: (1) the person wants to engage in that behaviour, (2) the person himself/herself is able to engage in that behaviour, and, (3) the circumstances allow that person to engage in that behaviour. This basic assumption explains the name of the Triad model, because for any behaviour to take place the same set of three conditions needs to be satisfied:

1. Motivation
2. Capacity (or capability)
3. Opportunity

Within the framework of the Triad model these three central concepts (henceforward referred to as the three Triad factors) that constitute the model, are defined as follows:

Motivation (M)*: To what extent does the person wish to attain a certain goal, or to what extent is the person interested in engaging in behaviour X. Motivation refers to existing attitudes as well as the appeal of rewards and results that are brought about by engaging in behaviour X.*

Capacity (C)*: To what extent does the person have the qualities, skills and instruments at his/her disposal to engage in behaviour X. Capacity refers to physical, mental (knowledge), and financial capacity and tools and aids available to that person.*

Opportunity (O)*: To what extent do the circumstances (beyond the control of the person) favour or hinder behaviour X. Opportunity refers to physical, material, weather, social and societal circumstances and the available time frame.*

In the above definitions 'behaviour X' refers to the behavioural alternative under investigation. Applying the Triad model for explaining or predicting behaviour X involves estimating the value of each of the three Triad factors. This basic principle of the Triad model is directly linked to the way this approach accommodates with the 'completeness' and 'practical applicability' issues discussed in Section 5.2. Applying the Triad model does not involve searching for the values of an infinite list of determinants, it only requires the estimation of values for three basic factors that enfold all relevant aspects[3] with respect to behaviour X.

Within the framework of the Triad model the values for the three factors determining the probability of behaviour X are estimated on a scale ranging from 0.0 to 1.0. If motivation, capacity and/or opportunity are estimated to be (very) high this is indicated by a score for that factor that is close to 1.0, whereas a factor score that is closer to 0.0 indicates low motivation, capacity or opportunity. The Triad model presupposes that explaining and predicting behaviour not only involves estimating the values of the three Triad factors, but also taking into account the mutual coherence of these concepts. Therefore, determining the probability of behaviour X amounts to estimating the values of the three Triad factors and combining these scores to one score that reflects to what extent behaviour X 'performs

[3] For an elaborate discussion on the 'completeness' of the Triad model, see [Poiesz, 1995] and [Poiesz, 1999].

well' on all three factors simultaneously. This score is referred to as the T_{score}, and can be depicted as follows (Equation 5.4):

(5.4) $$T_{score} = M * C * O$$

The fact that establishing the T_{score} for behaviour X involves multiplying[4] the three Triad factors indicates that establishing the probability of behaviour X refers to establishing to what extent the three basic conditions for engaging in behaviour X are met and that all of these conditions and their mutual coherence are important. Obviously, if the score for one of the three Triad factors is close to 0.0, the probability of behaviour X is close to 0.0 as well. In other words, if the person is either not motivated, nor capable to engage in behaviour X, or if the circumstances do not allow the person to engage in that behaviour, it is highly unlikely that behaviour X will occur and the T_{score} for that behaviour is close to 0.0 (a very low probability). Similarly, if a person is highly motivated and capable to engage in behaviour X, and the circumstances favour that behaviour, there is no reason whatsoever not to expect that person to engage in that behaviour and the T_{score} for behaviour X will be close to 1.0 (a very high probability).

The multiplicative character of the Triad model reveals some very interesting benchmarks for measures that aim at influencing the behaviour of consumers:

- Obviously, a very low score on one of the three Triad factors immediately results in a low probability for that behavioural alternative, and indicates a clear need to focus measures on that aspect.
- Within certain boundaries (for instance, if none of the Triad factors is very low), the overall probability of behaviour X can be enhanced by focussing on various combinations of Triad factors.
- It is extremely important to verify that measures aiming at enhancing the score for one particular Triad factor do not simultaneously negatively affect the score for the other Triad factors, because that could lead to ineffectiveness of the measure with respect to actually influencing the behaviour of concern, even if the measure seems to result in a higher score for the Triad factor it focussed on.

It is also important to note that each Triad factor is made up of an 'intrinsic' and an 'extrinsic' component, where the first refers to characteristics and thoughts of the person him/herself and the latter refers to outside influences. This characteristic of the Triad model accommodates the inclusion of aspects such as rewards (outside influence on motivation), the removal of barriers (outside influence on opportunity), and communication (see the findings by Van Meegeren [1997], as discussed in the previous Section) and handing tools and (financial) aids (outside influence on capacity). Simultaneously, the inclusion of 'intrinsic' *and* 'extrinsic' components allows for influencing the Triad factors beyond "appealing to a voluntary chance in behaviour based on a sense of shared responsibility" (see previous Section). Thereby, this characteristic of the Triad model is in full accordance with the findings presented in the previous Section of this Chapter, where it was concluded that 'intrinsic' components like normative influence, pro-environmental attitudes and

[4] For an elaborate discussion on and argumentation for the choice for a multiplicative model, see [Poiesz, 1995] and [Poiesz, 1999].

general environmental knowledge/concern alone constitute weak predictors of environmentally responsible behaviour, such as adequate disposal behaviour.

A final important characteristic of the Triad model that certainly deserves mentioning at this point, and one that accommodates the findings with respect to the habitual nature of environmentally relevant behaviour, is the fact that it presents the opportunity to monitor (the reasons for engaging in specific) behaviour in the course of time. The Triad model constitutes, in contrast to the TRA/TOPB and subsequent adjustments and extensions, a dynamic model, particularly suited to compare (the occurrence of) two (or more) behavioural alternatives (e.g. disposal by means of the refuse bag/bin versus handing in used products for recycling purposes) in time.

The dynamic character of the Triad model is shaped in first instance by the application of 'relative T_{scores}' versus 'absolute T_{scores}.' To illustrate this point, the following example deals with an examination of two behavioural alternatives available to a person in a specific situation: behaviour X and behaviour Y. The T_{score} for behaviour X is estimated at 0.78 and the T_{score} for behaviour Y at 0.65. While comparing these two behavioural options and trying to find an explanation for the choice of a person to engage in one of them, it is important to keep in mind that the Triad model does not represent an algorithm with mathematical precision. In other words, the 0.78 score for behaviour X does not represent a 78 % probability that the person will engage in behaviour X. However, the higher T_{score} for behaviour X in comparison to behaviour Y does indicate that that person is more likely to engage in behaviour X than in behaviour Y. This can be illustrated by calculating the 'relative T_{scores}' for both behavioural alternatives:

relative T_{score} behaviour X = 0.78/(0.78+0.65) = 0.55
relative T_{score} behaviour Y = 0.65/(0.78+0.65) = 0.45

In this particular example, behaviours X and Y are the only two behavioural alternatives available to that person, which means that the accumulated probabilities of X and Y amount to 1.0. Therefore, the relative scores for the two behavioural alternatives can be calculated as was done above, and the resulting scores indicate that there is a probability of 55 % that that person will engage in behaviour X. In designing measures to influence the behaviour of consumers, it is important to realise that the effectiveness of these measures is not so much determined by their ability to realise a higher 'absolute T_{score}' for the 'desirable' behaviour. The effectiveness of specific measures is primarily determined by their ability to ensure a higher 'relative T_{score}' for the 'desirable' behaviour in comparison to the 'undesirable' alternative. This notion shows how it is possible that some researchers have reported about situations in which governmental measures to encourage environmentally responsible behaviour have indeed resulted in higher 'motivation' and 'knowledge' levels with consumers without actually resulting in more 'desirable' behaviour by those consumers. Obviously, the measures applied in these situations were able to increase the T_{score} for the 'desirable' behavioural alternative, but the 'relative T_{score}' for that behaviour was still lower that the score for the 'undesirable' alternative. This notion illustrates the importance of accounting for all behavioural alternatives (and trying to influence their 'relative T_{scores}') available to consumers in designing environmentally responsible behaviour enhancing measures, instead of simply focussing on 'promoting' and 'recommending' one of the alternatives.

Environmentally responsible behaviour such as disposal behaviour constitutes a recurring activity, which means that influencing consumers to engage in a specific behaviour requires influencing the 'relative T_{scores}' for the behavioural alternatives in the course of time. With respect to this notion, the Triad model introduces some very important 'mechanisms' (that shape the dynamic character of the model even further) that need to be considered carefully in designing behaviour influencing measures. These mechanisms are closely related to 'self-fulfilling prophecies,' and they comprise an explanation for the obstinacy of many behavioural patterns (habits) and provide important benchmarks for "breaking off environmentally damaging habits" [Van Meegeren, 1997].

The first mechanism included in the Triad model is the so-called 'balance-effect.' This refers to the way in which the three Triad factors can stimulate each other. The second important mechanism deals with the opposite, the fact that the Triad factors can also hinder each other, resulting in an ever-decreasing T_{score} in the course of time. This phenomenon is called the 'spiral effect.'

For most behaviours, the goal of that behaviour is a given, which indicates that if that goal is appealing to a person his/her motivation to engage in that behaviour will be high. However, if the circumstances and required capacities (low scores on O and C) hinder that particular behaviour the person will probably try to make sure that he finds more favourable circumstances and look for additional tools and aids (increasing O and C). If that is possible, the overall T_{score} for that behaviour will increase and the behaviour becomes even more likely. This is called the 'primary balance effect.'

However, in some instances more favourable circumstances and additional tools and aids will not be available. The high score for motivation will not result in the possibility to actually engage in that behaviour, eventually resulting in a decreasing motivation. This is called the 'secondary balance effect' or 'spiral effect.' With respect to environmentally relevant behaviour, this effect could occur in situations where engaging in 'desirable' behaviour requires investing a lot of time, money and effort, and the possibilities to engage in that behaviour are unclear to the persons involved. For instance, handing in used 'small' consumer electronics in some municipalities requires consumers to either bring the used product to a retailer and buy a new one, or bring the old product to the local waste yard and having to pay a fee. These options require a lot of time, effort and money and many consumers are not even aware of these options. Therefore, it is not surprising that even if they are 'intrinsically' motivated to hand in used products for recycling purposes, the unfavourable circumstances and limited knowledge (low O and C) can very easily result in those persons not engaging in environmentally responsible disposal behaviour and their motivation to do so decreasing over time. Obviously, such a situation could easily result in a downward spiral development in M, O and C (the 'spiral effect'), because consumers can get frustrated by the unfavourable circumstances and required time, effort and money to engage in that behaviour, subsequently resulting in a lower motivation to look for better circumstances and increase their knowledge. In such situations, "environmentally damaging habits" [Van Meegeren, 1997] can easily arise and it will be extremely difficult to change those, because consumers will no longer be interested in (motivated to find) additional information and changing circumstances.

The above example advances some very important benchmarks for designing effective measures aimed at enhancing environmentally responsible behaviour by consumers.

Governmental strategies to promote/encourage this type of behaviour should not focus exclusively on 'motivation' aspects by educating and informing consumers about environmental problems. In many situations, the low probability (T_{score}) of consumers engaging in that behaviour is the direct result of unfavourable circumstances (barriers, see the previous Section), limited knowledge about specific behavioural alternatives available to them, and the obstinacy of habits developed in the course of time (as a result of 'old' O and C scores). Therefore, designing effective measures requires accounting for all three Triad factors simultaneously, instead of subsequently or even ignoring one or two, in order to prevent the occurrence of destructive 'balance and spiral effects.'

From all the above, it is clear that the Triad model offers the opportunity to incorporate the findings (e.g. with respect to the importance of barriers, extrinsic motivation (rewards) and habits) presented in the previous Sections in a framework that can accommodate with the limitations (with respect to 'applicability' and 'completeness') of available literature. Therefore, the Triad model is applied at various stages in the design effort presented in this thesis (as was indicated in the introduction to the discussion of the model itself) in an effort to incorporate all relevant theoretical perspectives in the analysis and as a means to ensure mutual coherence between the various design stages. In the next Section, the Triad model is applied in an attempt to provide a more structured analysis (exemplification) of the results of the pilot projects presented in Chapter 4.

5.5 An exemplification of the results of pilot projects based on the Triad model

The Apparetour/Collection project described in Section 4.2 revealed that the clusters (groupings of municipalities) that put more collection routes at consumers' disposal achieved significantly higher collection rates than clusters with fewer routes. A similar outcome emerged with respect to comparing high frequency curbside collection services with low frequency curbside collection services. With hindsight, by means of applying the Triad model, these results are obvious. It would be reasonable to assume that for consumers in different clusters the scores for the Triad factors motivation and capacity (M and C) are similar. However, the circumstances surrounding the disposal behaviour of consumers in different clusters do diverge. In clusters with more collection routes available to consumers, it is easier for these consumers to hand in their used consumer electronics in an environmentally responsible manner. What's more, if used consumer electronics are collected at the consumers' houses (curbside collection) and if the frequency of this curbside collection is higher, it becomes more and more convenient for these consumers to engage in 'desirable' behaviour. Therefore, the circumstances in these clusters favour the 'desirable' behaviour much more than in clusters without curbside collection and less collection routes. In Triad terms this means that the score for circumstances (O) is higher and with similar scores for M and C this obviously results in higher T_{scores} for the 'desirable' behaviour. Therefore, the Triad model provides a straightforward confirmation of the conclusion that more collection routes, more convenient collection routes and higher frequencies for curbside collection for consumers with similar motivation and capacity levels will result in higher collection rates.

Simultaneously, the results of the Apparetour/Collection project revealed that only 45% of the consumers in the region of the pilot project were aware of the project and its objectives, which points to a low 'knowledge level' and subsequently a low score for the Triad factor

capacity (C). Therefore, it is not surprising that in those clusters where curbside collection is not applied, and consequently cannot play a role in enhancing the 'awareness' of consumers, the collection rates are very low, because low scores for C and O obviously result in a low T_{score} for 'desirable' behaviour. In fact, it is not at all far-fetched to assume that 'secondary balance effects' have discouraged consumers to engage in that behaviour even more. Three surveys that were conducted within the framework of Apparetour/Collection indicated that consumers considered the refuse bag/bin as a convenient and customary (!) disposal route, even though they still indicated to prefer handing 'small' consumer electronics over to the municipality. This notion seems to point to a situation in which unfavourable circumstances, lack of specific knowledge about available collection routes and high efforts required for the 'desirable' behavioural option (i.e. low scores for C and O) have, in the course of time, resulted in a decreased level of motivation (low score for M) and therefore a low probability that these consumers will engage in 'desirable' behaviour in the future without any additional interventions.

Finally, the results from the special campaign in Geldrop illustrate the fact that interventions that address all Triad factors simultaneously can result in significant improvements. The campaign in Geldrop combined additional publicity campaigns and curbside collection with door-to-door efforts to persuade people to participate, thereby simultaneously exerting influence on M, C and O and consequently considerably enhancing the T_{score} for appropriate disposal behaviour. The results from this 'special' intervention were in accordance with what could be expected based on a Triad analysis; a considerable amount of 'extra' collected 'small' appliances.

Analysing the WeBbak-project, described in Section 4.3, results in a similar conclusion with respect to the influence of circumstances as in the Apparetour/Collection project. The municipalities that placed the WeBbak containers near parking lots and shopping malls achieved significantly higher collection rates than the municipalities that placed these containers at a municipal waste yard. Dropping off used consumer electronics at a place 'on route' is far more convenient than having to transport used consumer electronics to a place that is 'off route,' which can be translated in a higher score for circumstances (O) and a higher score for capacity (C; less effort and time required, so it is far more likely that consumers will have enough time to spare) in the first situation. Obviously, the motivation levels (score for M) can be assumed similar for all consumers involved in this project, and therefore, the T_{score} for consumers in the first group of municipalities will be higher. This Triad analysis shows that the higher collection rates for these municipalities logically ensue from the more convenient placing of the WeBbak containers.

The Delft-project, described in Section 4.4, resulted in remarkably high collection rates. The set-up of this project involved combining a lottery based reward system (influencing extrinsic motivation, thereby enhancing the score for M) with a convenient bring system (enhancing the score for O) and a publicity campaign specifically focussing on the set-up of this particular project (increasing the knowledge level of consumers, thereby enhancing the score for C). The success of this project is in full accordance with the Triad notion that interventions that simultaneously address all three Triad factors constitute the most effective strategies to promote/encourage 'desirable' behaviour. Simultaneously, the success of the reward system applied in the Delft-project is in full accordance with the underlying argumentation of the Triad model that motivation levels can be influenced

(positively) by focussing on 'extrinsic motivation' and the findings presented in Section 5.3.

The RCS-project, described in Section 4.5, revealed that 81 % of the consumers in the targeted region was aware of the pilot project and 80 % of those consumers indicated that they were motivated to hand over used 'small' consumer electronics at the designated collection points. However, sorting analyses of household waste performed within the framework of this project indicated that a number of these consumers still disposed of their used appliances by means of the refuse bag/bin. A Triad analysis of this observation suggests that enhancing the T_{score} for appropriate disposal behaviour, by means of a convenient bring system combined with a reward system, can still prove to be ineffective for a portion of the consumers. Apparently, inappropriate disposal behaviour still remains the preferred option to some consumers, even after increasing the M and O scores for appropriate behaviour. This observation illustrates the importance of analysing the 'relative T_{scores}' of both behavioural alternatives in the course of time. In fact, enhancing the effectiveness of measures to promote/encourage 'desirable' behaviour could very well require additional measures to discourage/block 'undesirable' behavioural alternatives.

The RCS2-project, described in Section 4.6, combined a higher number of collection routes than the Delft-project and the RCS-project. However, the achieved collection rates were not significantly higher. This observation could very well be the result of another important difference between the RCS2-project and the other two. In the RCS2-project consumers were not rewarded for handing in used appliances. In Triad terms this means that the RCS2-project focussed more on circumstances (O) and less on motivation (M) than the other two projects. However, the Triad model indicates that the scores for all three Triad factors combined determine the probability of consumers engaging in 'desirable' behaviour. Therefore, 'neglecting' one Triad factor cannot be smoothed away by trying to increase the score for another Triad factor more and more, especially if the score for the 'neglected' factor is relatively low.

The project in Vorden, described in Section 4.7, advances a further illustration for the analysis presented above about the effectiveness of interventions that address all three Triad factors simultaneously. However, this project revealed one specific additional 'lesson.' The reward system that was applied in this project was lottery based for the first period of time and based on 'small' cash discounts for the latter stages. The achieved collection rates for these two time spans differed considerably, even though it would be reasonable to assume that the 'intrinsic' motivation and knowledge levels of consumers did not change significantly and the circumstances remained unchanged. Obviously, even the slightest decrease in the T_{score} for the 'desirable' behavioural alternative by means of a decrease in 'extrinsic' motivation (part of M) was enough to discourage consumers to engage in that behaviour. This observation substantiates the importance of addressing all Triad factors simultaneously and the potentially destructive effect of ignoring or neglecting one of them. Simultaneously, this observation substantiates the importance of analysing the 'relative scores' of all behavioural alternatives, because obviously the slightest decrease in the 'objective score' for one alternative can be enough to shift the balance in favour of the 'undesirable' alternative.

The latter is illustrated by the results of the curbside collection system in North-Veluwe, also described in Section 4.7. The results for one municipality in that project were

significantly better than the results for the other participating municipalities. What differentiated this municipality from the others was the coupling of the curbside collection system with a weight-based charging system for regular household waste collection services. In Triad terms, this municipality not only promoted the 'desirable' behaviour, but also simultaneously discouraged the 'undesirable' alternative by decreasing the 'extrinsic' motivation (M) of that behaviour. Once again, this expounds the importance of focussing on the 'relative T_{scores}' of the behavioural alternatives available to consumers for measures aiming at influencing their behaviour in an environmentally responsible direction.

The final pilot project described in Chapter 4 dealt with an elementary school based collection system. This project simultaneously addressed all three Triad factors, by educating scholars ('intrinsic' M and C), providing a convenient collection point (O) and including a reward ('extrinsic' M). Not surprisingly, this project proved to be a success.

5.6 A Triad analysis of the current Product Recovery Network

Chapter 2 of this thesis already analysed the current Product Recovery Network for consumer electronics in the Netherlands extensively. This Section certainly does not aim at simply redoing that analysis, but rather to provide an alternative approach to examine the current disposal system, especially with respect to the behavioural consequences of the system. The latter is directly related to the objective of Chapter 6; to generate design alternatives for measures that could influence consumer behaviour with respect to the disposal of 'small' consumer electronics in an environmentally desirable direction. The remainder of this Section therefore presents a Triad analysis, based on the findings of Chapters 4 and 5, of the current Product Recovery Network and the behavioural patterns of consumers regarding the disposal of 'small' consumer electronics, as they have been established in Chapter 2. The results of this analysis constitute the main point of departure for the next stage in the design effort presented in this thesis, i.e. the *synthesis* stage. Accordingly, this Section concludes the *analysis* stage of this design effort.

Within the framework of the Disposal of white and brown goods Decree (see Chapter 2, and [Staatsblad 238, 1998]) that came into effect in 1998, consumers are supposed to dispose of their used 'small' consumer electronics by making use of one of the separate collection routes for these products. For the vast majority of consumers (with the exception of people living in specific regions that participate(d) in some of the pilot projects mentioned in Chapter 4) this means that they can dispose of their used 'small' consumer electronics in two ways:

1. When purchasing a similar new product, they can hand over the old product to the retailer or supplier (the 'selling' party) free of charge.
2. They can hand over their old product to the municipality, sometimes by means of curbside collection, but usually only by means of bringing these products to the municipal waste yard. What's more, even though these services are supposed to be free of charge, indicated in [Informatiecentrum Preventie en Hergebruik, 1998] and [Staatsblad 238, 1998], some municipalities require consumers to pay an additional fee to make use of these services (see Chapter 4).

Section 2.3.2 already showed that before 1998 a very common way of disposal for 'small' consumer electronics was to put the discarded products in the refuse bag/bin. Unfortunately (from an environmental perspective), the separate collection routes that were installed by virtue of the Disposal of white and brown goods Decree [Staatsblad 238, 1998] only account for a small portion of the total amount of discarded 'small' consumer electronics since 1998, as was described in the remainder of Chapter 2. Therefore, one can only conclude that consumers are persisting in their long since habit of throwing 'small' appliances in the refuse bag/bin. The subsequent Triad analysis could provide an explanation for this observation, thereby establishing some important reference points for the development of measures to improve this situation (the topic of Chapter 6 of this thesis).

As indicated in Section 5.4, the Triad model presupposes that for any individual to engage in a specific behavioural alternative the same set of three conditions (Triad factors) need to be satisfied: motivation, capacity, and opportunity. Therefore, trying to find an explanation for the above observation by means of a Triad analysis requires an estimation of the values of these three factors for both the desirable behavioural alternative (disposal of 'small' consumer electronics by means of the separate collection routes set up within the framework of the Disposal of white and brown goods Decree [Staatsblad 238, 1998]) and the current/undesirable behavioural alternative (disposal of 'small' consumer electronics by means of the refuse bag/bin).

First of all, with respect to *opportunity* it is important to note that the desirable behavioural alternative usually requires consumers to invest time, effort, and sometimes even money (as indicated above). Bringing the used product to the municipal waste yard can be quite time consuming and sometimes requires the consumer to use a car (because of the distance and having to transport the used products) and/or even pay a fee. Similarly, handing over used products to retailers requires consumers to buy a new product at the same time, which can definitely come down to a significant barrier to make use of this disposal option. A simple example could illustrate this point quite clearly:

> *One fine day, someone that has been applying an electric razor for years decides to switch to shaving by hand, because of persistent skin rash after every shave. Obviously, the electric razor is of no use to him any longer and this is not the kind of appliance that you would give away (most people would not want to use a second hand electric razor). Therefore, he would like to hand over this 'small' electric appliance that has become superfluous to the retailer that sold it to him. However, at the retailer's he is told that he can only hand in the old electric razor if he buys a new one. Obviously, having made the choice to switch to shaving by hand, he is not interested in a new appliance and is forced to retain the old one.*

Similarly, handing in a used product at a retailer has to (according to the Decree) take place at the same time that a new similar product is bought. However, especially with respect to 'small' consumer electronics, a good deal of these purchases can be characterised as 'unplanned' and 'on the spur of the moment.' Consequently, the consumer usually has not brought the old product at the time of the purchase and he/she is not allowed to hand in the old product at a later time.

The above clearly indicates that within the current Product Recovery Network for 'small' consumer electronics, certainly in the view of the consumer, the environmentally responsible disposal options available to consumers do not always favour desirable behaviour. In fact, it seems justified to conclude that the current Product Recovery Network for consumer electronics in the Netherlands hinders desirable disposal behaviour with respect to 'small' consumer electronics. Therefore, in Triad terms, the value for *opportunity (O)* can be estimated as *low*.

Secondly, with respect to *capacity* a very notable observation relates to the advertising campaigns that have been applied by the Dutch government and especially the NVMP. The central message of these campaigns has been (and continues to be, as indicated by B. Vonkeman (managing director of the NVMP)): "Zonder U valt er niets te recyclen!" This exclamation could be translated in English as: "Without you, there is nothing to recycle!" This type of campaign can be characterised as a general "appeal to a voluntary change of behaviour" [Van Meegeren, 1997] without specifying the exact behaviour that is intended and all (dis)advantages involved. In fact, it would be reasonable to assume that a number of consumers are not aware of the specific collection routes for 'small' consumer electronics available to them[5] and the type of campaigns applied by the Dutch government and the NVMP to encourage/promote appropriate behaviour has not contributed to resolving this lack of specific knowledge. This and related issues are discussed in more detail in Chapter 8 of this thesis, but at this point, in light of the analysis presented in this Section, the value for *capacity (C)* can be estimated as *low*.

Finally, with respect to *motivation* it is important to recall the conclusion from Section 2.5 that the overall trend that can be deduced from research in this field [RIVM/CBS, 2001] is that general interest in environmental issues and environmental awareness (defined as willingness to invest time and effort) among Dutch consumers is certainly not rising and is lower nowadays than it was before. This observation suggests that *intrinsic motivation* levels of consumers to engage in environmentally responsible behaviour, especially behaviour that requires time and effort to be invested such as disposal of 'small' consumer electronics, are not high. The fact that quite a lot of friends, relatives, neighbours, and so on do not engage in that behaviour either, certainly gives no rise to the assumption that social norms could resolve this issue. Similarly, one can only assume that *extrinsic motivation* levels will not be any higher, because the current disposal system incorporates no specific rewards and/or penalties to promote the desirable behavioural alternative. In fact, the discussion above regarding *opportunity* suggests the opposite (e.g. if a fee is required for handing in used products at the municipal waste yard). Furthermore, the low values for *capacity* and *opportunity* regarding appropriate disposal behaviour for 'small' consumer electronics and the unavailability of alternative collection routes to most consumers indicate a high probability of the materialisation of the so-called 'secondary balance effect' or 'spiral effect' (see Section 5.4), which would have a detrimental effect on the already low *motivation* levels. Recapitulating all the above unarguably leads to the conclusion that the value for *motivation (M)* can be estimated as *low*.

[5] This conclusion is based on discussions with the supervisory commission installed within the framework of the IOP-project "Zware Metalen/Consumentenelectronica", representatives from the Dutch Ministry of Housing, Spatial Planning and the Environment, and scientists, and on personal experience (inquiring a large number of friends, relatives, colleagues, acquaintances, and so on).

A similar analysis for the current/undesirable behavioural alternative (disposal of 'small' consumer electronics by means of the refuse bag/bin) results in a significantly deviant image. Whereas disposing of 'small' consumer electronics by means of the refuse bag/bin is extremely convenient (*high* value for *opportunity*) and known to all consumers (*high* value for *capacity*), this undesirable behavioural alternative results in no immediate negative consequences and what's more, it relieves the consumer of the burden of having to retain the obsolete product and remember to bring it along to the retailer or the municipal waste yard. Other than a possible 'sense of guilt,' this behavioural option results in only positive consequences (*high* value for *motivation*) for consumers involved. Therefore, based on all the above and the previous findings of Chapters 4 and 5 of this thesis, it seems highly unlikely that this 'sense of guilt' would reduce the motivation levels significantly enough to restrain them from engaging in the undesirable behavioural alternative.

All the above is summarised in Table 5.1 hereunder, supplemented with the resulting T_{scores} for the desirable and the undesirable behavioural alternatives:

Factor scores for the two behavioural options and resulting T_{score}				
disposal option	*opportunity*	*capacity*	*motivation*	*resulting* T_{score}
separate collection routes	low	low	low	low
refuse bag/bin	high	high	high	high

Table 5.1: Triad analysis of disposal options for 'small' consumer electronics

Based on the above Triad analysis, it is not at all surprising that the analysis presented in Chapter 2 of this thesis revealed that the current Product Recovery Network for consumer electronics in the Netherlands results in low collection rates for 'small' consumer electronics. Consequently, this analysis does provide some important reference points with respect to the development of measures to enhance these collection rates. More specifically, the Triad analysis presented above enables the establishment of the "essential aspects that must be incorporated" [Cross, 1994] in these measures. This notion concludes the *analysis* stage of the design effort presented in this thesis and, thereby, constitutes the point of departure for the next stage: the *synthesis* stage (Chapter 6).

Chapter 6

The synthesis stage

Generating design alternatives for collection rate enhancing measures

6.1 Introduction

This thesis enfolds a design process as a means to develop collection rate enhancing measures for 'small' consumer electronics in the Netherlands. Adhering to the work by Jones [1981, 1984], as indicated in Chapter 3, such a design process can be systematised by subsequently effectuating the following stages: (1) analysis, (2) synthesis, and finally, (3) evaluation.

Following the initial problem analysis described in Chapters 1 through 3, Chapters 4 and 5 consummated the *analysis* stage of the design effort presented in this thesis. This Chapter describes the *synthesis* stage of that design effort and aims at generating relevant design alternatives for measures to enhance collection rates for 'small' consumer electronics in the Netherlands.

The synthesis stage of a design process can be defined as follows:

"Finding possible solutions for each individual performance specification and building up complete designs from these with least possible compromise." [Jones, 1981/1984]

For a 'standard' design process dealing with tangible products such an approach is pretty obvious and straightforward, even though it may require quite a considerable contribution of creativity by the designer(s) to succeed [Cross, 1994]. However, the objective of this thesis is not to develop or redesign any tangible product, but rather to design (policy) measures that could enhance collection rates for 'small' consumer electronics in the Netherlands. The main "performance specification" [Jones, 1981/1984] for these measures relates to the way in which they will succeed in influencing (Dutch) consumer behaviour in an environmentally desirable direction; i.e. encourage consumers to dispose of their used 'small' consumer electronics by means of specifically dedicated collection routes, instead of disposal by means of the refuse bin/bag or any other environmentally detrimental disposal option. Relevant "solutions" [Jones, 1981/1984] involve measures that could succeed in accomplishing such a behavioural change at 'reasonable' costs from a political, societal and business economic perspective. The latter is the topic of Chapters 7 and 8 of this thesis, whereas this Chapter focuses on generating "possible solutions" [Jones, 1981/1984].

However, before addressing the actual generation of design alternatives, and based on the 'non-standard' characteristic property of the design effort described in this thesis, the next Section first of all attempts to provide a bird's-eye view overview of the design process as a whole. The main reason for providing this more generic discussion consists in clearly

positioning the *synthesis* stage, as it is described in this Chapter, and the *evaluation* stage, as it is described in Chapter 7, within the framework of specific steps that typically need to be executed within such a process and the mutual coherence between these steps. The latter specifically refers to the way in which the results of a specific stage (e.g. the analysis stage) in the design process logically serve as points of reference for a subsequent stage (e.g. the synthesis stage), especially with respect to establishing the functions required of a new design and the performance required of design solutions. The choice to pay additional attention to this 'translation' of the results of the *analysis* stage, presented in Chapters 1 through 5 of this thesis, into clear points of reference for the following stages rests on the 'unusual' character of the design object.

The remaining Sections of this Chapter are specifically dedicated to the generation of design alternatives for collection rate enhancing measures (see Figure 6.1). In these Sections, the Morphological Chart Method [Cross, 1994] is successively applied to generate subsolutions for the list of subfunctions (the functions required of the new design) and to combine these subsolutions in "possible solutions" [Jones, 1981/1984], or design alternatives.

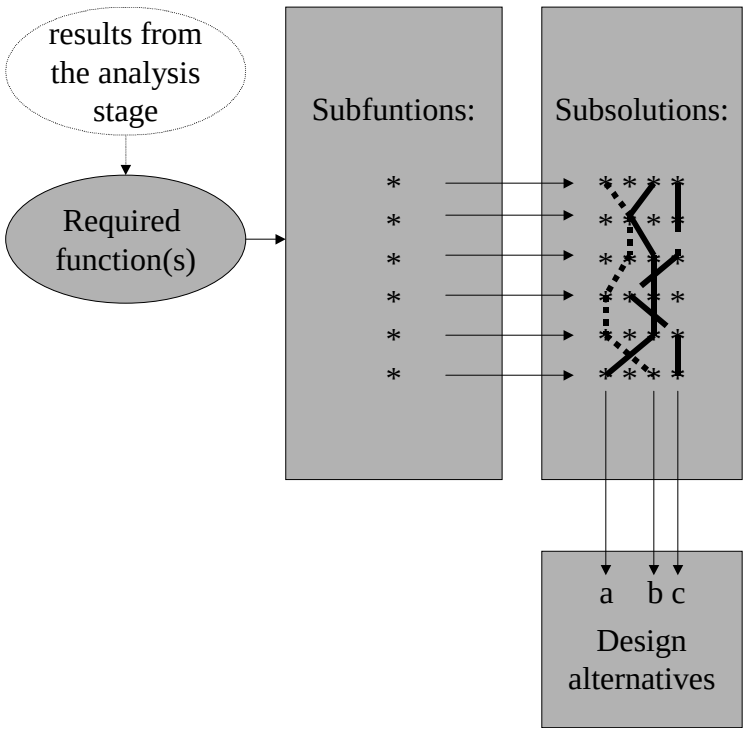


Figure 6.1: Schematical overview of the applied design methodology.

First of all, Section 6.3 focuses on establishing the "essential aspects that must be incorporated" [Cross, 1994] in the measures to be developed. This is based on the results of the *analysis* stage and the translation of these results into functions required of a new design (described in Section 6.2). Worded differently, the results of the analysis of the

current disposal system, as presented in previous Chapters, and the subsequent interpretation of these results in Section 6.2 are applied to derive the complete set of subfunctions that need to be performed by the measures to be designed.

Subsequently, Section 6.4 provides possible subsolutions with respect to these individual subfunctions by means of the Morphological Chart Method [Cross, 1994]. That same method is applied in Section 6.5 to identify feasible combinations of these subsolutions, which results in the establishment of a set of design alternatives (conceptual designs) for collection rate enhancing measures. This set of design alternatives constitutes the point of departure for the next and final stage in the design process, i.e. the evaluation stage (Chapters 7 and 8).

6.2 A bird's-eye view: positioning the synthesis and evaluation stages

According to Cross [1994] the following seven steps, representing a more detailed description of the way the analysis, synthesis and evaluation stages should be effectuated, cover a complete design process:

1. Clarifying objectives
2. Establishing functions
3. Setting requirements
4. Determining characteristics
5. Generating alternatives
6. Evaluating alternatives
7. Improving details

For a more elaborate general discussion on these design steps, see [Cross, 1994]. This Section indicates how (and where) these steps are (or have already been) executed in the specific design process included in this thesis.

First of all, Chapters 1 and 3 of this thesis have already indicated how the overall objective (the project context) of the research project that formed the basis for this thesis has been complemented with a specific project research objective to contribute to achieving this goal. In accordance with this objective, and based on the results of the analysis presented in Chapters 1 through 5, this Chapter aims at designing (generating design alternatives for) measures to enhance collection rates for 'small' consumer electronics in the Netherlands. Obviously, this goal represents the **design objective (step 1)** for this process.

However, as pointed out by Poiesz [1999], it is crucial to realise that one of the main causes for measures to prove ineffective in practice is "thinking in terms of goals instead of the behaviour that people have to engage in to achieve that goal" in the course of designing these measures. In this particular situation, the goal that needs to be achieved by the measures to be designed has so far been referred to as the resulting collection rates for 'small' consumer electronics in the Netherlands. However, a more precise analysis of this situation (see Chapter 2) learns that these collection rates are the direct result of the disposal behaviour of consumers and consequently, the measures to be designed need to be directed towards that behaviour. In fact, without being pernickety, it would be fair to say that the goal that needs to be achieved by the measures to be designed is not so much to enhance

collection rates, but rather *to influence the behavioural patterns of consumers that currently dispose of their used 'small' consumer electronics by means of the refuse bag/bin and to persuade them to make use of separate collection routes for these products (that have been installed or will be installed as an integral part of the designed measures) within the framework of the Disposal of white and brown goods Decree*. This 'translation' of the overall goal establishes the **main (generic) function (step 2)** required of measures to be designed.

In Section 5.4 of this thesis, it was concluded that the effectiveness of measures designed to influence the behaviour of consumers is determined by their ability to ensure a higher 'relative T_{score}' for the desirable behavioural alternative in comparison to the undesirable alternative. Therefore, the main function required of measures to be designed, as it was indicated above, immediately advances two specific **subfunctions (step 2, continued)** that need to be performed by these measures:

1. Reduction of the T_{score} for the undesirable behavioural alternative, i.e. the disposal of 'small' consumer electronics by means of the refuse bag/bin.
2. Enhancement of the T_{score} for the desirable behavioural alternative, i.e. disposal of 'small' consumer electronics by means of the separate collection routes (that have been installed or will be installed as an integral part of the designed measures) within the framework of the Disposal of white and brown goods Decree.

The establishment of the main (generic) function and two subsequent subfunctions, as it is presented above, constitutes the first part of the so-called function analysis. This function analysis ultimately results in establishing all relevant subfunctions that need to be performed by relevant design alternatives. This analysis is continued and concluded in Section 6.3 as a first step in applying the Morphological Chart Method to **generate** these design **alternatives (step 5)**.

Consequently, these design alternatives constitute the point of departure for the next step in the design process, i.e. **evaluating** these **alternatives (step 6)**, which is the topic of Chapter 7 of this thesis.

Obviously, this evaluation needs to be based on a set of appropriate (performance) criteria. Logically, each new design needs to perform the functions required of that design (see above). This requirement usually is expressed by the term effectiveness, and Chapter 7 shows that within the framework of this thesis this criterion also covers the environmental consequences mentioned in the overall objective for this project (see Chapters 1 and 3). Furthermore, most new designs need to perform these functions at the lowest costs possible. Even though collection rate enhancing measures represent a rather 'unusual' design object, the overall objective that forms the basis for this thesis and, thereby, the included design effort, indicates that costs (i.e. economic consequences, see Chapters 1 and 3) certainly need to be included in adjudging the performance of specific design alternatives as well. This requirement usually is expressed by the term efficiency. Finally, the specific character of the design object, collection rate enhancing measures that need to be effectuated within the framework of the existing Product Recovery Network for 'small' consumer electronics in the Netherlands, signifies the importance of specifically addressing the feasibility of specific design alternatives. The extent to which specific measures can be integrated into existing social, legal, business and organisational structures could play a

pivotal role in the ultimate choice for a specific alternative to be selected for the next step in the design process, i.e. **improving details[1] (step 7)**.

The above discussion constitutes a first outset for **setting requirements (step 3)** that establish the set of (performance) criteria that are applied in the evaluation stage. This process is continued (in more detail) and concluded in Chapter 7 of this thesis, preceding the actual evaluation of alternatives. However, whereas this step usually requires "setting limits" [Cross, 1994], for instance with respect to the costs (what the client is prepared to spend on a new machine), size, or weight of the final design, the 'unusual' character of the design object under consideration in this thesis makes setting limits a priori impossible. Answering questions with respect to what costs are societally acceptable and what efforts to integrate the measures into existing structures in order to achieve specific (levels of) collection rates are societally feasible are typical examples of political deliberations. These deliberations are discussed in more detail in Chapters 7 and 8, but providing a final answer to these questions, if at all possible, lies beyond the scope of this thesis. Therefore, for the design effort presented in this thesis, this step does not include setting quantitative limits a priori, even though qualitative deliberations about the societal acceptability and feasibility of specific (sub)solutions, partly based on a sense in advance of the effectiveness and efficiency (see above), obviously are incorporated in the choice for a specific set of design alternatives to be included in the evaluation stage. Chapter 7 presents a more elaborate discussion with respect to these criteria in order to establish the exact measures needed to evaluate the selected design alternatives in more detail.

The above overview of the design process presented in this thesis, and the coherence and situation of the execution of these steps, still lacks one of the seven steps mentioned at the start of this discussion, i.e. determining characteristics. However, the fact that this step is missing from the design process presented in this thesis is a direct result of the 'unusual' contents of the design object and the results of the analysis stage. As indicated by Cross [1994], the aim of this step of the design process is "to set targets to be achieved for the engineering characteristics of a product." The next Section shows how the Triad analysis presented in the final Section of the previous Chapter immediately results in establishing the complete list of subfunctions that are required from the new design. Additional characteristics such as weight, texture and rigidity, that play an important role in the design of tangible products, obviously are not (immediately) applicable to an intangible design object such as collection rate enhancing measures. Therefore, all this makes this step unnecessary for the specific design effort presented in this thesis.

With that last notion, the bird's-eye view overview of the design process as a whole, as it is presented above, can be concluded. All relevant steps and the mutual coherence have been established for the next Section to return to the actual design steps that need to be executed.

[1] *At this point, it is important to note that the actual execution of this final design step lies beyond the scope of this thesis, because the ultimate decision with respect to the selection of the most appropriate design alternative to be the subject for this stage of the design process specifically depends upon deliberations within a political and institutional context. This topic is discussed in more detail in Chapter 8 of this thesis.*

6.3 Establishing the 'list of subfunctions' required of the new design

The last Section of Chapter 5 presented a Triad analysis of the current Product Recovery Network for consumer electronics in the Netherlands and the resulting behavioural patterns of consumers with respect to the disposal of 'small' consumer electronics. The results of this analysis have been summarised in Table 5.1.

Subsequently, the first part of the function analysis, as it was presented in the previous Section, established two specific subfunctions that need to be performed by measures to be designed:

1. Reduction of the T_{score} for the undesirable behavioural alternative (refuse bag/bin).
2. Enhancement of the T_{score} for the desirable behavioural alternative (separate collection).

This Section continues and concludes this function analysis by establishing the complete 'list of subfunctions' that need to be incorporated in the ultimate design alternatives, based on all the foregoing.

With respect to the effectiveness of measures to be designed, Sections 5.4 and 5.5 indicated the importance of accounting for all three Triad factors that determine the T_{score} for a specific behavioural alternative simultaneously, instead of subsequently or even ignoring one or two factors, in order to prevent the occurrence of destructive 'balance and spiral effects.' The factor scores of the two behavioural alternatives under observation in this Chapter (established by the two specific subfunctions that need to be performed), as indicated in Table 5.1, substantiate the importance of this notion in this particular design effort even further. The desirable behavioural alternative that needs to be promoted by the measures to be designed currently can be characterised as showing low scores for all three Triad factors, whereas the undesirable alternative incorporates high scores for all three factors.

Therefore, the reduction of the T_{score} for the undesirable behavioural alternative (disposal by means of the refuse bag/bin) requires the simultaneous reduction of the values for motivation, opportunity and capacity for this behaviour (M_u, O_u, C_u), whereas the enhancement of the T_{score} for the desirable alternative (disposal by means of separate collection routes) requires the simultaneous enhancement of the values for motivation, opportunity and capacity for this behaviour (M_d, O_d, C_d). Poiesz [1999] states that such a combined strategy (discouraging the undesirable alternative and encouraging the desirable alternative) "only makes sense if both types of measures are launched simultaneously," once again, in order to prevent the occurrence of destructive 'balance and spiral effects.'

Consequently, based on all the above, it can be concluded that the measures to be designed need to perform six subfunctions simultaneously: the reduction of the values for M_u, O_u, and C_u, and the enhancement of the values for M_d, O_d, and C_d. Therefore, in terms of the Morphological Chart Method, these six subfunctions constitute the "essential aspects that must be incorporated" [Cross, 1994] in the measures to be designed; the 'list of subfunctions' (Figure 6.2).

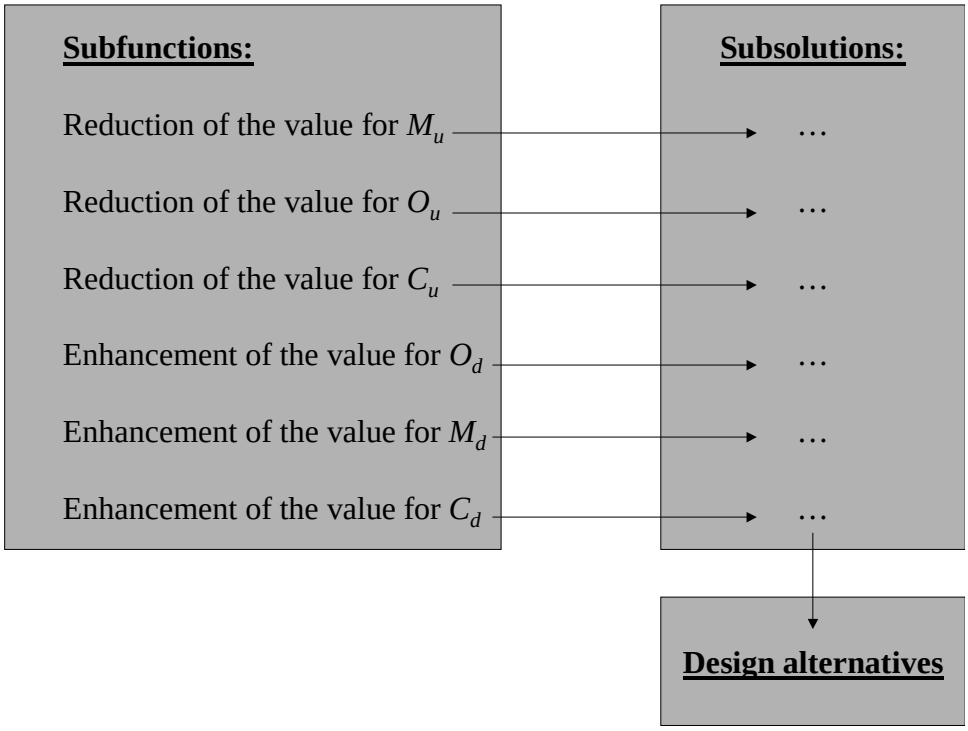


Figure 6.2: The results of phase 1 of the Morphological Chart Method: Establishing the list of subfunctions

6.4 Generating possible subsolutions for the six subfunctions

This Section establishes possible subsolutions for all of the subfunctions that need to be performed by the measures to be designed, as they have been established in the previous Section. As pointed out by Cross [1994], "the generation of solutions is, of course, the essential, central aspect of designing," and can also be described as "to make a proposal for something new – something which does not yet exist," or even, "a mysterious act of creativity." Simultaneously though, "making variations on established themes is (...) an important feature of design activity," and "creativity can often be seen as the reordering or recombination of existing elements" [Cross, 1994]. Therefore, the remainder of this Section provides a mixture of both elements, creativity and reordering/recombination, and is grounded on the imagination of the designer (i.e. the author of this thesis) and a critical re-examination of the findings in Chapters 4 and 5 of this thesis, as well as suggestions by Poiesz [1995/1999] and others[2]. The quintessence of the discussion hereunder is to provide

[2] Based on discussions with the supervisory commission installed within the framework of the IOP-project "Zware Metalen/Consumentenelectronica", representatives from the Dutch Ministry of Housing, Spatial Planning and the Environment, and scientists, and on personal experience (inquiring a large number of friends, relatives, colleagues, acquaintances, and so on).

'all'[3] possible subsolutions for each of the six established subfunctions and this, combined with the "mysterious" (see above, [Cross, 1994]) element that forms an important foundation for this design stage, eventuates in an analysis that can be characterised as listing "the means by which it might be achieved" [Cross, 1994]. Therefore, in the discussion below, for each of the six subfunctions that were established in the previous Section, a number[4] of possible subsolutions is listed and, if necessary, illustrated.

Generating subsolutions for the reduction of the value for M_u (subfunction 1)

The analyses in the previous Chapters have revealed that the undesirable behavioural alternative (disposal by means of the refuse bag/bin) results in no immediate negative consequences and, what's more, it relieves the consumer of the burden of having to retain the obsolete product and remember to bring it along to the retailer or the municipal waste yard. Other than a possible 'sense of guilt' based on an "awareness of consequences" [Pieters, 1989], this behavioural option results in only positive consequences for consumers involved. These observations offer some specific benchmarks for establishing possible approaches (subsolutions) to reducing the value for M_u.

First of all, keeping in line with the traditional approach by the Dutch government and the NVMP/ICT Milieu (see Chapters 2, 5 and 8), one could aim at creating an "awareness of consequences" [Pieters, 1989], thereby possibly activating a 'sense of guilt' as a result of "responsibility acceptance" [Pieters, 1989], with respect to engaging in this behavioural alternative. This possible 'sense of guilt' is directly related to the 'complex' social dilemma (see Subsection 5.3.3) that is represented by disposing of 'small' consumer electronics by means of the refuse bag/bin. Increasing the "awareness of consequences" and "responsibility acceptance" needed to activate this 'sense of guilt' at least requires educating and informing people about the environmental consequences of their actions and relates to trying to influence the *intrinsic motivation* of consumers. Obviously, this is closely related to a possible lack of knowledge and the absence of any feedback with respect to engaging in this behavioural alternative. Whereas the former refers to increasing the knowledge level of consumers (decreasing C_u, which is discussed later in this Section), the latter refers to the possibility that "intrinsic factors can be caused by constantly experiencing extrinsic factors" [Poiesz, 1999]. The fact that this behaviour results in no (immediate) negative consequences and only results in positive consequences is directly related to the *extrinsic motivation* to engage in this behavioural alternative. Therefore, confronting consumers with (immediate) negative consequences and removing the positive

[3] As a consequence of creativity constituting a significant element of this analysis, this objective/requirement obviously represents a subjective measure. Furthermore, listing all feasible solutions with respect to measures designed to influence consumer behaviour inevitably results in subjective judgements with respect to ethical and moral feasibility, as opposed to physical and constructural patterns that would limit the feasibility of tangible solutions/components.

[4] In accordance with the applied design methodology [Cross, 1994] this step strives for generating 'all' possible subsolutions. This means that some subsolutions that are listed might raise some questions with respect to societal acceptability. However, at this point in the design process, only those subsolutions for which it is evident that they are unacceptable are omitted.

consequences could possible reduce both the intrinsic and extrinsic components of the motivation to engage in the undesirable behavioural alternative (M_u).

Removing the positive consequences, i.e. the relieve of the burden of having to retain the obsolete product and remember to bring it along to the retailer of the municipal waste yard, would imply making it impossible to dispose of 'small' consumer electronics by means of the refuse bag/bin (or other 'inappropriate' means for that matter) and is discussed under the heading "Generating subsolutions for the reduction of the value for O_u" below.

Confronting consumers with negative consequences could involve feedback, fines, and extra costs. However, these subsolutions require the proper authorities to be informed about consumers engaging in the undesirable behavioural alternative. Therefore, this eventuates in the requirement to install some sort of monitoring service. The contents of refuse bags/bins would need to be analysed and inspected for 'small' consumer electronics. In practice, this could either come down to analysing the contents of the garbage truck(s) or the individual garbage bags/bins of consumers. Whereas the former would imply that feedback, fines and extra costs could only be attributable to groups of consumers, the latter would enable the proper authorities to confront individual consumers with feedback, fines and extra costs.

An alternative subsolution (although possibly a little extreme) would be to analyse the contents of the accumulated waste of all consumers in a specific municipality (or even the Netherlands), by means of representative samples, and invoice the inhabitants of those municipalities (or the Netherlands) by means of additional (local) taxes based on the portion of 'small' consumer electronics found.

With respect to charging consumers that engage in the undesirable behavioural alternative extra costs, the concept of weight based charging systems for regular household waste constitutes an alternative means of confronting consumer with negative consequences. Consumers that dispose of 'small' consumer electronics by means of the refuse bag/bin obviously will be confronted with higher invoices based on the extra weight.

Summarising all the above results in establishing the following (theoretically) possible subsolutions specifically aimed at the reduction of the value for M_u:

1. Additional (local) taxes, based on an analysis of representative samples.
2. Reprimand groups of consumers, based on analysing the contents of garbage trucks.
3. Fine groups of consumers, based on analysing the contents of garbage trucks.
4. Invoice groups of consumers, based on analysing the contents of garbage trucks.
5. Reprimand individual consumers, based on analysing the contents of individual garbage bags/bins.
6. Fine individual consumers, based on analysing the contents of individual garbage bags/bins.
7. Invoice individual consumers, based on analysing the contents of individual garbage bags/bins.
8. Invoice individual consumers, based on weighing individual garbage bags/bins.

Generating subsolutions for the reduction of the value for O_u (subfunction 2)

Executing this subfunction is directly related to a significant problem with respect to discouraging consumers to engage in undesirable behaviour. Reducing the opportunity to engage in this type of behaviour would imply creating circumstances that hinder or even make it impossible to dispose of 'small' consumer electronics by means of the refuse bag/bin. As mentioned in Chapter 5, opportunity refers to physical, material, weather, social and societal circumstances and the available time frame.

Given the fact that 'small' consumer electronics easily fit into a refuse bag/bin, making it physically impossible to dispose of these products by means of the refuse bag/bin requires some sort of monitoring/inspecting of the disposal behaviour of individual consumers. Monitoring/inspecting the act itself, which usually takes place inside the private home of the consumer, is obviously not a realistic option. Therefore, the only ethically feasible way to accomplish this and hinder (make impossible) this behaviour would imply monitoring/inspecting the contents of the refuse bag/bin. Actually making the undesirable behavioural option impossible would require inspection of each and every refuse bag/bin on containing 'small' consumer electronics, whereas hindering the behaviour could be accomplished by random checks. The obvious next step would be to return the 'small' consumer electronics to the consumer in question, thereby confronting them with immediate negative consequences and removing the positive consequences by redirecting the burden of having to dispose of the obsolete product in an appropriate way to the consumer. In other words, these two subsolutions regarding the reduction of the physical component of O_u eventuate in additional immediate negative consequences and the removal of positive consequences for consumers, thereby also contributing to the reduction of M_u. Therefore, these two subsolutions constitute possible subsolutions for the execution of both these subfunctions (reduction of O_u + reduction of M_u).

A possibly more feasible alternative would be to provide (immediate) feedback to groups of consumers, e.g. about the number and types of appliances in their household waste (possibly with a list of all heavy metals included and the health risks associated with these materials) on the basis of an analysis of representative samples, thereby reducing the opportunity of consumers to feel 'unaware' about their behaviour. More popularly worded, this subsolution aims at reducing the opportunity of consumers to 'get away' with 'inappropriate' behaviour.

Regarding social and societal circumstances, and the weather hindering undesirable behaviour, these aspects of the opportunity to engage in the disposal of 'small' consumer electronics by means of the refuse bag/bin offer little perspective for feasible solutions. However, it is important to realise that making it impossible for consumers to dispose of obsolete products in that way could 'stimulate' them to seek for alternative disposal options, such as illegal dumping. Therefore, successfully reducing the opportunity to dispose of products by means of the refuse bag/bin encompasses a possible environmentally detrimental side effect and this effect should be accounted for concurrently. For this type of behaviour, e.g. illegal dumping, social and societal circumstances do play an important role. Reducing the opportunity for consumers to engage in this type of behaviour requires ensuring a significant chance for consumers to get caught in the act and be reprimanded/fined either by fellow citizens or proper authorities. Creating these social and societal circumstances requires quite a drastic culture swing in the present-day Dutch

society. However, an in-depth analysis of these particular problems certainly lies beyond the scope of this thesis.

Generating subsolutions for the reduction of the value for C_u (subfunction 3)

Capacity refers to physical, mental (knowledge), and financial capacity and tools and aids available to consumers to dispose of 'small' consumer electronics by means of the refuse bag/bin. With respect to tools and aids available, it would be infeasible to take away the refuse bags/bins from consumers to make it impossible to engage in undesirable behaviour. Obviously, reducing the physical capacity of consumers does not offer any feasible subsolutions either. However, with respect to financial and mental capacity a few possible subsolutions could be established.

The financial capacity of consumers to engage in inappropriate disposal behaviour could be reduced by introducing fines and invoices for any 'small' consumer electronics that have been detected in the household waste of that consumer. Therefore, some of the subsolutions presented in order to reduce M_u can also present valuable subsolutions for the reduction of the financial component of C_u.

Mental capacity offers some alternative reference points for introducing subsolutions that could reduce the capacity of people to engage in undesirable behaviour. A possible 'sense of guilt' (as a result of an "awareness of consequences" and "responsibility acceptance" [Pieters, 1989]) could prove to constitute a significant (mental) barrier for (some) consumers to engage in that behaviour. Therefore, capitalising on this barrier to prevent people from disposing of their obsolete products by means of the refuse bag/bin could be enhanced by (immediate) feedback about the environmental problems that are caused by this particular behaviour. Some of the monitoring activities mentioned as part of the subsolutions for the reduction of M_u could possibly be combined with specific educational activities, e.g. handing out leaflets and invitations to information meetings about the actual consequences of their actions to consumers engaging in the undesirable behavioural alternative.

As indicated above, a precondition for the activation of a possible 'sense of guilt' to act as a (metal) barrier to engage in undesirable behaviour is that consumers are aware of (and understand) the consequences of their actions. A lack of knowledge concerning the environmental problems caused by 'small' consumer electronics could account for consumers not being troubled by a 'sense of guilt' as a result of their current disposal behaviour. While feedback could eliminate this lack of knowledge afterwards, eliminating this lack of knowledge beforehand requires more general (for all consumers) educational campaigns and this type of measures presents an alternative range of subsolutions in the field of reducing C_u (advertising, commercials on TV, leaflets, and so on). In other words, these subsolutions amount to reducing C_u by reducing the "unawareness of consequences" of consumers, thereby possibly activating a latent mental barrier ('sense of guilt').

Generating subsolutions for the enhancement of the value for O_d (subfunction 4)

Within the current set-up (in practice) of the Product Recovery Network for consumer electronics in the Netherlands, consumers can either hand in their 'small' consumer electronics at the retailer where and at the time they buy a new product, or at the municipal

waste yard. As discussed in the previous Section, this situation eventuates in a low value for O_d, especially due to the amounts of time, effort and money that are required to make use of these separate collection routes that were installed within the framework of the Disposal of white and brown goods Decree [Staatsblad 238, 1998].

Logically, a subsolution for the enhancement of the opportunity for consumers to avail themselves of these collection routes would be to reduce the amounts of time, effort and money that are involved with these disposal options. More generally, these two collection routes should be adjusted in such a way that they represent more convenient ways to dispose of 'small' consumer electronics.

With respect to handing in obsolete products at a retailer, a significant barrier for consumers to employ this disposal option is constituted by the precondition that a consumer has to simultaneously buy a similar new product to be allowed to hand in the old one. Therefore, enhancing the opportunity with regard to this disposal option could be achieved by loosening this precondition. Some examples of subsolutions that would satisfy this benchmark are:

- Allowing consumers to hand in 'small' consumer electronics whenever they buy a new product at that retailer, even if it is not a similar product.
- Allowing consumers to hand in 'small' consumer electronics at a later stage, for instance based on showing the sales slip (or some specific voucher) for the similar new product they bought at a previous visit to that specific retailer.
- Allowing consumers to hand in 'small' consumer electronics at any retailer (and at a later stage) after buying a similar new product, for instance based on showing the sales slip (or some specific voucher) for the similar new product they bought at a previous visit to another retailer.
- Allowing consumers to hand in 'small' consumer electronics without the obligation to buy a new product.

Regarding the municipal waste yard, one of the most significant barriers for consumers to hand in their obsolete products at this collection point is formed by the fee that is required at some waste yards. Obviously, enhancing the opportunity for this particular collection route certainly requires the abolishment of such fees. Some other examples of subsolutions that could also enhance the value of O_d are:

- More convenient (broader) opening hours, for instance weekends.
- A separate counter for handing in 'small' consumer electronics.
- More local waste yards, closer to the residences of consumers.

The above-mentioned lists certainly do not represent all possible subsolutions that are conceivable for these two collection routes, but they do represent a number of clear examples of how the existing routes could be made more convenient for consumers. However, adjusting the existing collection routes only presents a portion of the subsolutions that could be developed to enhance the value for O_d. Another collection of subsolutions for the execution of this particular subfunction is composed of installing additional separate collection routes for consumers to hand in their 'small' consumer electronics. Chapters 4 and 5 already advanced a number of 'new' collection routes that could be applied to make

the disposal of these products more convenient for consumers. The list hereunder reflects some examples of this category of subsolutions:

- Collection points at retailers other than the ones mentioned above. With respect to this solution, it is important to note that the resulting value for O_d can be influenced by the choice of the situation and the density of these collection points. For instance, a car dealer represents a collection point that is not frequented by most consumers, whereas a supermarket usually represents a daily stop. Therefore, situating collection points for 'small' consumer electronics at supermarkets entails a higher value for O_d than situating them at car dealers, or consumer electronics retailers for that matter (the current location of collection points). Similarly, a higher density of collection points represents a higher value for O_d.
- The placement of a (street-)container (the so-called WeBbak, see Chapter 4) as a collection point for 'small' consumer electronics. Once again, the situation and the density of these collection points influence the resulting value for O_d. For instance, locating the containers near parking lots and supermarkets represents a more convenient disposal route for consumers than locating the containers at municipal waste yards outside of the town/city centre.
- Curbside collection of 'small' consumer electronics, either on call or by means of regular/scheduled rounds. The frequency and timing of the rounds made by the collection vehicle once again influences the value for O_d.
- Collection points at schools, community centres, sports centres, and so on.
- Distribution of bags or mini-containers to consumers that can be used to store and transport obsolete 'small' consumer electronics.
- A separate compartment for 'small' consumer electronics in the refuse bins for regular household waste.
- A separate compartment (or additional container) for 'small' consumer electronics in the garbage truck used to collect regular household waste, so that the collection of regular household waste can be combined with curbside collection of 'small' consumer electronics.

Generating subsolutions for the enhancement of the value for M_d (subfunction 5)

Similarly to the subsolutions for the reduction of the value for M_u, the subsolutions for the enhancement of M_d could focus on either enhancing the *intrinsic* component of motivation, or the *extrinsic* component, or exploiting the principle that "intrinsic factors can be caused by constantly experiencing extrinsic factors" [Poiesz, 1999].

First of all, the *intrinsic* component of M_d relates to concepts such as environmental awareness and environmental concern. Activating these mechanisms could require providing information and education about the environmental problems that result from inappropriate disposal of 'small' consumer electronics. Therefore, subsolutions that directly aim at activating the intrinsic component of M_d are discussed under the heading "Generating subsolutions for the enhancement of the value for C_d."

Under the current heading, the subsolutions that are presented aim at providing *extrinsic motivation* to consumers (possibly contributing to *intrinsic motivation* in the long run) to dispose of 'small' consumer electronics by means of appropriate collection routes, either

the ones that are already installed within the framework of the Disposal of white and brown goods Decree [Staatsblad 238, 1998], or additional separate collection routes that are installed within the framework of collection rate enhancing measures (for instance the ones suggested above). Extrinsically motivating consumers to engage in the desirable behavioural alternative could involve measures such as requests, instructions, legal provisions, and various types of rewards. Regarding the latter, rewards could be comprised of mechanisms such as positive feedback (as opposed to the reprimands mentioned as part of the possible subsolution for the reduction of M_u), but also monetary rewards, either in the capacity of cash discounts, money, or lottery tickets. In the context of the disposal of 'small' consumer electronics, some examples of the way specific subsolutions for the execution of this subfunction could be installed are listed hereunder:

- Requests or instructions distributed by the Dutch government, local authorities, or the NVMP/ICT Milieu to encourage, entreat or even instruct consumers to avail themselves of the installed separate collection routes for 'small' consumer electronics.
- Legal provisions (local or national) that enforce consumers to avail themselves of the installed separate collection routes for 'small' consumer electronics.
- Providing positive feedback to groups of consumers (for instance specific municipalities) based on the high collection rates of 'small' consumer electronics or low percentages of 'small' consumer electronics in regular household waste collected from that group of consumers.
- Group rewards for specific groups of consumers (for instance, the inhabitants of specific municipalities or a school, sports club, and so on) based on the amount of collected 'small' consumer electronics. Rewards could be constituted of lower taxes, a tax refund, or even tangible rewards (for instance, the computers in the school based collection system described in Chapter 4).
- A reward for individual consumers at the time of handing over obsolete products, for instance at a retailer, at the municipal waste yard, or to the collection vehicle that tends to curbside collection. Imaginable rewards could, for instance, be:
    - (vouchers for) cash discounts at retailers
    - monetary compensation
    - (vouchers for) tangible rewards, for instance an 'environmentally responsible' souvenir
    - some sort of lottery ticket, giving consumers the chance to win cash discounts, money or tangible rewards
- Introducing some sort of deposit money ordinance, for instance, requiring consumers to pay a fee at the point of acquiring the product and returning that fee at the point of handing in the product at an appropriate collection point.
- Introducing a weight-based charging system for regular household waste, eventuating in lower invoices for consumers that avail themselves of appropriate collection routes for the disposal of 'small' consumer electronics, instead of throwing obsolete products in the refuse bag/bin.
- Goal-setting techniques, for instance like in the school based collection system described in Chapter 4.

Generating subsolutions for the enhancement of the value for C_d (subfunction 6)

As mentioned above, providing information and education about the environmental problems that result from inappropriate disposal of 'small' consumer electronics could play an important role in activating the *intrinsic* component of M_d. It is quite possible that (groups of) consumers could be intrinsically motivated to contribute to solving/preventing environmental problems, but are not aware of the specific problems related to 'small' consumer electronics and the way separate collection of these products could contribute to a solution of these problems. In other words, a low value for the knowledge component of C_d prevents these consumers from engaging in the desirable behavioural alternative and, therefore, a possible subsolution for the execution of this subfunction (the enhancement of C_d) is comprised of providing specific information concerning the importance and background of this topic.

Another subsolution that could play a pivotal role in activating and especially preserving the intrinsic motivation of consumers consists of providing specific feedback about the progress of the efforts to solve the problems mentioned above, and the way in which separately collected 'small' consumer electronics are handled. Consumers that are motivated to dispose of their obsolete products in appropriate ways will be interested to know the results/effect of their efforts. A lack of knowledge, a low value for C_d, with respect to the actual progress of the collection and processing of 'small' consumer electronics and the resulting environmental gains could have a detrimental effect on the value for M_d of these consumers.

It is also quite possible that consumers are motivated to engage in the desirable behavioural alternative and the circumstances favour this particular behaviour, but simultaneously lack knowledge about the collection routes available to them. Similarly, consumers can be prone to react positively to measures focusing on enhancing extrinsic motivation and opportunity, but lack knowledge about these measures. Obviously, this lack of knowledge will have a detrimental effect on the effectiveness of these measures and the resulting collection rates. Therefore, beyond general information and education about environmental problems related to 'small' consumer electronics, informing consumers about existing and additional measures to enhance collection rates constitutes a critical aspect of any measure to be designed and introduced. For any reward, new collection point, or curbside collection service to be successful, consumers at least need to be aware of these measures and the resulting new possibilities.

All the above indicates that consumers need to be informed and educated about environmental problems and the progress of efforts to resolve these problems, but simultaneously, to prevent the occurrence of detrimental 'balance and spiral effects,' about practical issues concerning collection routes, available rewards and products that need to be handed over (and how). This information could be provided in various ways, for instance:

- Promotional campaigns on TV and radio, or by means of posters, leaflets, (local) advertisements in papers, magazines, and so on, by either the Dutch government, local authorities, and the NVMP/ICT Milieu.
- Letters addressed to individual consumers.
- Informational meetings.
- Leaflets, folders, instructions to be handed over at the moment of purchase.

- Education on schools.

In addition to these subsolutions aiming at resolving a lack of knowledge, other subsolutions regarding the enhancement of the value for C_d could focus on the physical and financial capacity, and tools and aids available to consumers to dispose of 'small' consumer electronics by means of appropriate collection routes. One example of a subsolution with respect to tools and aids has already been advanced as a subsolution to enhance O_d, i.e. providing consumers with a bag or container that can be used to store and transport 'small' consumer electronics. Regarding physical and financial capacity, it is quite obvious that abolishing the fees at municipal waste yards and the precondition of having to buy a similar new product at a retailer (e.g. for consumers with limited financial means) and the situation of collection points (e.g. for consumers without a car) can play a pivotal role in enhancing C_d. A number of examples of this type of subsolutions have been discussed above.

This concludes the generation of possible subsolutions for the execution of the six subfunctions that have been established in Section 6.3. Some examples of these subsolutions have been included and properly situated in Figure 6.3 to illustrate the conclusion of this step within the framework of the Morphological Chart Method applied in this Chapter.

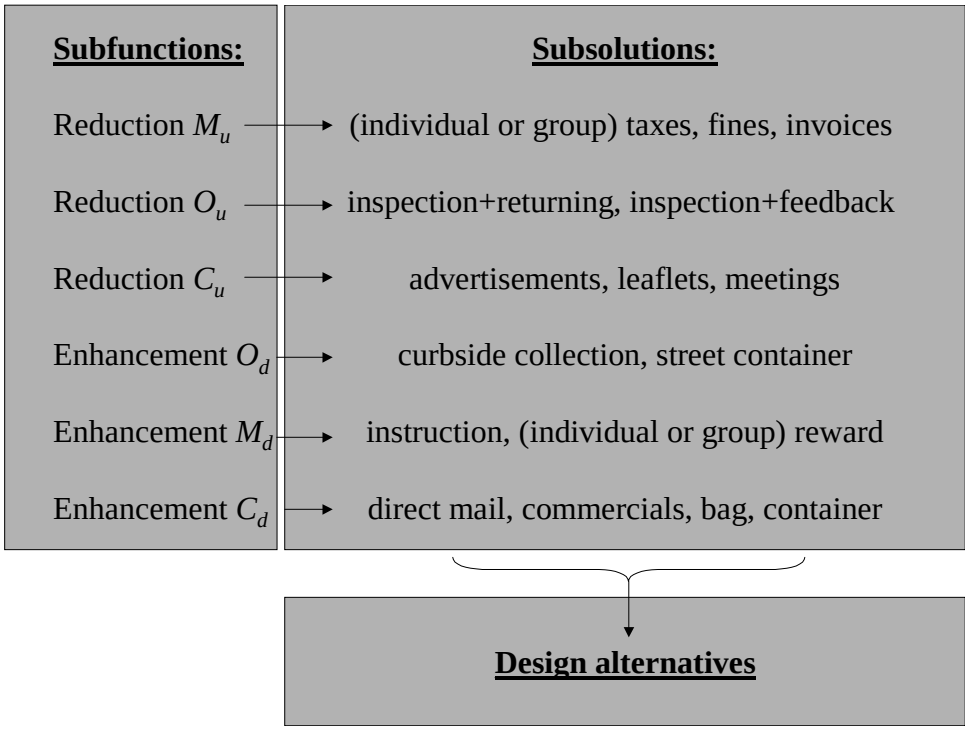


Figure 6.3: The results of phase 2 of the Morphological Chart Method: Generating the list of possible subsolutions for the execution of each of the six subfunctions

6.5 Generating relevant design alternatives, based on all the foregoing

Generally speaking, establishing all possible design alternatives (solutions, or conceptual designs) within the framework of applying the Morphological Chart Method involves listing all subfunctions required of the new design and all possible subsolutions for the execution of each of these subfunctions in one grid [Cross, 1994], as illustrated by Figure 6.3. At that point, the Morphological Chart contains "the complete range of all the theoretically-possible different solution forms" and "the complete range of solutions consists of the combinations made up by selecting one subsolution at a time from each row" [Cross, 1994]. However, in the specific design effort presented in this thesis following such a straightforward prescript would result in at least 10,500 (see [5]) design alternatives. In fact, this number only represents the number of theoretically-possible solutions that could be constructed by means of picking one subsolution at a time from each row. With respect to the development of measures as discussed in this thesis however, in contrast to the general reference point for a design effort aiming at the development of a tangible product, it is not at all impossible to combine several subsolutions from one row in a particular design alternative. For instance, it would be quite imaginable to combine the introduction of collection points at retailers or supermarkets with curbside collection of 'small' consumer electronics. Similarly, it would also be imaginable to construct feasible and effective design alternatives made up of less than six subsolutions. For instance, if the selected subsolution with respect to reducing O_u would result in a situation in which it is impossible for consumers to engage in the undesirable behavioural alternative, there is no need to include additional subsolutions for the execution of the other two subfunctions related to discouraging the undesirable behaviour. Therefore, the final number of theoretically-possible design alternatives that can be constructed based on all the subsolutions generated in the previous Section is even higher than the number mentioned above. Obviously, it would be practically impossible and unreasonable to execute an in-depth evaluation of all of these design alternatives. Consequently, this step in the synthesis stage requires some sort of selection process to determine a specific set of design alternatives that are relevant to be included in the next step of the design effort, i.e. the evaluation stage.

As a reference point for this selection process, it is important to re-establish the fact that, generally speaking, collection rate enhancing measures/mechanisms represent intangible societal provisions. A design process aiming at developing such measures represents a significantly different process than a design effort aiming at the development of a tangible product for a commercial company, for instance an industrial machine or consumer appliance. These differences mostly relate to concepts such as problem-ownership (in this case, the society as a whole, represented by the Dutch government, local authorities and the NVMP/ICT Milieu) and decision rules (e.g. political deliberations, ethical, societal and legal boundaries, and competition/market considerations) that are applied and accounted for by these parties in the ultimate choice for the specific measures that will be worked out and

[5] A rough scan of the range of subsolutions presented in the previous Section results in the following estimations for the minimum number of feasible subsolutions for the execution of the six subfunctions:
for Mu ≅ 10, # for Ou ≅ 3, # for Cu ≅ 5, # for Od ≅ 14, # for Md ≅ 10, # for Cd ≅ 5.
Therefore, the number of design alternatives is: 10 * 3 * 5 * 14 * 10 * 5 ≅ 10,500.

installed in practice. These aspects are discussed in more detail in Chapter 8 of this thesis, but it would be presumptuous to assume that this thesis can provide a completely accurate analysis and especially a completely accurate prediction of the influence of these aspects on the utilisation of the findings in this thesis in practice.

Considering the circumstances described above, the choice for the most efficacious set of design alternatives to be included in the evaluation stage within this thesis is both based on the findings in Chapters 4 and 5 (with respect to the effectiveness of specific solutions/measures) and on an optimal (to the best of the author of this thesis' ability) prognosis of the adjudication of the (societal, ethical, political, economical, and so on) feasibility and acceptability of specific measures/mechanisms. This prognosis is based on an "intuitive (...) search of the [Morphological] chart" [Cross, 1994] for relevant design alternatives on grounds of a sense in advance of the effectiveness, efficiency and feasibility of specific combinations of subsolutions. In addition, a concrete bench mark available as a further underpinning of this selection process is constituted by the (sub)solutions that are included in the pilot projects discussed in Chapter 4 of this thesis. It would be reasonable to assume that the applied (sub)solutions represent a range of (sub)solutions that are regarded as 'feasible' and 'acceptable' by the initiators of these projects, the same set of parties mentioned above.

Taking into account all of the above, the following concrete design alternatives (solutions) are generated by combining one or more subsolutions (Section 6.4) for the execution of each of the six subfunctions (Section 6.3):

Design alternative 1

This design alternative is partly based on the success of the collection of glass/plastic bottles in the Netherlands. The central element of the current collection system for glass/plastic bottles is the placement of a high number of collection points near supermarkets and other places that are frequented by most consumers. For glass without 'deposit money' street containers are placed on parking lots near supermarkets, whereas for bottles with 'deposit money' collection points are situated inside supermarkets. Based on the findings in Chapter 4, particularly the disadvantages of the WeBbak as a collection point for 'small' consumer electronics, this design alternative applies mini-containers inside supermarkets instead of street-containers on parking lots and so on. The central elements of this design alternative are formed by making it more convenient for consumers to hand in their used 'small' consumer electronics and rewarding them for engaging in 'appropriate' disposal behaviour.

The specific subsolutions (selected from Section 6.4) that are combined to generate this design alternative are:

1. With respect to the reduction of the value for C_u (two subsolutions are included):
    a. Activating a possible 'sense of guilt' (see Section 6.4) by educating consumers about the environmental consequences related to the disposal of 'small' consumer electronics by means of the refuse bag/bin. Means applied to educate consumers include leaflets handed over to the consumer at the time of purchase of the product, commercials on TV, education of scholars by means of school projects, and advertisements in newspapers and magazines.

   b. Municipalities adjust local taxes based on the amount of 'small' consumer electronics detected in regular household waste, by including a clear variable invoice component entitled "handling 'small' consumer electronics." The latter directly reduces the financial capacity of consumers.
2. With respect to the reduction of the value for O_u:
   a. Direct feedback to consumers by the municipality about the environmental and financial consequences of their behaviour, based on analysing the contents of representative samples of the regular household waste of groups of consumers (streets, districts, municipalities). This feedback reduces the opportunity of consumers to feel 'okay' or 'unaware' about their behaviour (popularly worded: reducing the opportunity to 'get away' with inappropriate behaviour).
3. With respect to the reduction of the value for M_u (two subsolutions are included):
   a. Direct feedback to consumers by the municipality about the environmental and financial consequences of their behaviour, based on analysing the contents of representative samples of the regular household waste of groups of consumers (streets, districts, municipalities). Municipalities inform consumers about the effect of their disposal behaviour on local waste taxes, explaining the financial consequences of having to deal with 'small' consumer electronics in regular household waste.
   b. And, of course, municipalities actually adjust local taxes[6] based on the amount of 'small' consumer electronics detected in regular household waste, by including a clear variable invoice component entitled "handling 'small' consumer electronics." Confronting consumers with these negative consequences (negative feedback and taxes) reduces the extrinsic component of motivation, possible resulting in a reduction of the intrinsic component over time as well.
4. With respect to the enhancement of the value for O_d (two subsolutions are included):
   a. Situating collection points at supermarkets, analogous to the already existing collection points for 'deposit money' bottles.
   b. Distribution of special carrier bags to consumers that can be used to transport 'small' consumer electronics to the supermarket.
5. With respect to the enhancement of the value for M_d (two subsolutions are included):
   a. Lower local waste taxes based on a lower invoice component for 'small' consumer electronics if and when the amount of 'small' consumer electronics in regular household waste decreases (see 1b and 3b).

[6] An important notion with respect to this solution, that needs to be considered in the "improving details" stage of the design process, is that the continued effectiveness of design alternative 1 in the course of time could very well be best served by constructing this "tax solution" as a temporary measure. This to ensure that in the long run, the continued 'punishment' as a result of a specific group of consumers persisting in the undesirable behavioural alternative, will not evolve in a 'de-motivating' factor for consumers that have changed their behaviour in the desired direction.

b. Rewarding consumers for handing in 'small' consumer electronics at the collection point in supermarket by presenting them with a lottery ticket for a lottery with substantial money prizes (for instance, a so-called "kraslot").

6. With respect to the enhancement of the value for C_d (two subsolutions are included):
    a. Informing consumers about the 'new' collection route and the rewards involved by means of posters at the collection points, direct mail, commercials on TV, advertisement in newspapers and magazines, and leaflets handed over to the consumer at the moment of purchase. The messages emphasise the increased convenience for consumers and the rewards available to them (analogous to the Delft-project described in Chapter 4).
    b. Distribution of special carrier bags to consumers that can be used to transport 'small' consumer electronics to the supermarket. These bags serve as a tool/aid for consumers to store and transport their used products and simultaneously inform consumers about the appropriate/maximum size of consumers electronics to be handed in at the collection points inside supermarkets.

From all the above, it is clear that this design alternative (and a similar observation applies to design alternative 2 described below) requires the co-operation of a number of parties to be effectuated in practice, e.g. supermarkets, carriers connected to these supermarkets and the NVMP/ICT Milieu, the NVMP/ICT Milieu and municipalities. Therefore, the willingness to participate of these 'stakeholders' certainly deserves further attention in the remainder of the analysis presented in this thesis (see Chapters 7 and 8).

Design alternative 2

This design alternative is partly based on the success of the collection of paper in the Netherlands. The central element of the current collection system for paper is the curbside collection by means of a special truck. This design alternative also specifically applies the findings in Chapter 4 with respect to the advantages of combining a curbside collection system for 'small' consumer electronics with a weight-based charging system for regular household waste. The central elements of this design alternative are formed by making it more convenient for consumers to hand over their used 'small' consumer electronics and financially 'punishing' them for engaging in 'inappropriate' disposal behaviour.

The subsolutions (selected from Section 6.4) that are combined to generate this design alternative are:

1. With respect to the reduction of the value for C_u (two subsolutions are included):
    a. Activating a possible 'sense of guilt' (see Section 6.4) by educating consumers about the environmental consequences related to the disposal of 'small' consumer electronics by means of the refuse bag/bin. Means applied to educate consumers include leaflets handed over to the consumer at the time of purchase of the product, commercials on TV, education of scholars by means of school projects, and advertisements in newspapers and magazines.

b. Reducing the financial capacity of consumers to dispose of their 'small' consumer electronics by means of introducing a weight-based charging system for regular household. Individual consumers are invoiced for regular waste collection services based on the weight of their refuse bags/bins.

2. With respect to the reduction of the value for O_u:
    a. Direct feedback to individual consumers by the municipality about the financial consequences of their behaviour, based on the weight of their refuse bags/bins (as an integral part of the weight-based charging system). This feedback reduces the opportunity of consumers to feel 'okay' or 'unaware' about their behaviour (popularly worded: reducing the opportunity to 'get away' with inappropriate behaviour).
3. With respect to the reduction of the value for M_u:
    a. Introducing a weight-based charging system for regular household waste. Individual consumers are invoiced for regular waste collection services based on the weight of their refuse bags/bins, thereby confronting them with direct negative consequences as a result of disposing of 'small' consumer electronics by means of the refuse bag/bin.
4. With respect to the enhancement of the value for O_d (two subsolutions are included):
    a. Curbside collection of 'small' consumer electronics, combined with regular household waste collection services (high frequency, known collection days).
    b. Distribution of special mini-containers that can be used to store the used 'small' consumer electronics. These containers can either be placed at the curbside on collection days alongside the refuse bags, or connected to the refuse bin for regular household waste that is placed at the curbside on collection days (for instance by adding matching pegs on these container, or some other sort of convenient connector). To prevent the unauthorised opening of these mini-containers, they can be equipped with special safety locks that can only be opened by collection services personnel.
5. With respect to the enhancement of the value for M_d (two subsolutions are included):
    a. Introducing a weight-based charging system for regular household waste, resulting in lower invoices for consumers that apply the 'new' mini-container instead of the regular refuse bag/bin for 'small' consumer electronics.
    b. Direct positive feedback to individual consumers that apply the 'new' mini-container, for instance by means of a 'thank-you note' or a fitting/symbolic present.
6. With respect to the enhancement of the value for C_d (two subsolutions are included):
    a. Informing consumers about the 'new' collection route, instructions for use of the 'new' mini-container, and the rewards involved (lower invoices for regular waste collection services) by means of direct mail (by the municipality), commercials on TV, advertisements in (local) newspapers and magazines.
    b. Distribution of special mini-containers that can be used to store the used 'small' consumer electronics and place them at the curbside on collection

days. Obviously, these mini-containers constitute an additional tool/aid available to consumers to assist them in engaging in disposing of 'small' consumer electronics by means of the appropriate collection route.

To further the interpretation and valuation of the outcome of the evaluation of these design alternatives, the results are compared with the results of an evaluation of current strategies applied by the Dutch government, local authorities and the NVMP/ICT Milieu to encourage/promote the collection of 'small' consumer electronics. These strategies can be constructed as a concrete 'design alternative,' within the framework of the Morphological Chart Method applied in this Chapter, as indicated below.

Design alternative 3

This design alternative is based on the current strategies applied by the Dutch government, municipalities and the NVMP/ICT Milieu to enhance collection rates for 'small' consumer electronics. The central element of these current strategies is formed by promotional campaigns to convince consumers to change their behaviour and a number of pilot projects on a temporary basis. Therefore, the central elements of this design alternative are formed by informing/educating consumers and specific local measures to enhance O_d, M_d, and C_d within the framework of pilot projects.

The subsolutions (selected from Section 6.4) that are combined to generate this design alternative, are:

1. With respect to the reduction of the value for C_u:
    a. Activating a possible 'sense of guilt' (see Section 6.4) by 'informing' consumers about the fact that environmentally responsible processing of 'small' consumer electronics can only be realised if consumers hand in their used products by means of the appropriate collection routes. Means applied to 'inform' consumers include(d) commercials on TV, posters on busses, trains and billboards that display the message "Recycling cannot be done without you."
2. With respect to the reduction of the value for O_u:
    a. -
3. With respect to the reduction of the value for M_u:
    a. Activating a possible 'sense of guilt' (see Section 6.4) by educating consumers about 'shared responsibility' in general by means of commercials on TV. The central message of these commercials is "De maatschappij dat ben jij," which can be translated in English as "The society, you are the society." Some of these commercials specifically address disposal behaviour, mainly with respect to street rubbish.
4. With respect to the enhancement of the value for O_d:
    a. Various pilot projects, as discussed in Chapter 4 of this thesis. However, so far these pilot projects have not resulted in nationwide, structural adjustments in the collection routes available to consumers.
5. With respect to the enhancement of the value for M_d (two subsolutions are included):
    a. Encouraging a 'voluntary behavioural change' by means of appealing to collective responsibility. The means applied for this appeal have been mentioned above (1a and 3a).

b. Various pilot projects, as discussed in Chapter 4 of this thesis. However, so far these pilot projects have not resulted in nationwide, structural adjustments in the collection routes and accompanying motivational elements available to consumers.

6. With respect to the enhancement of the value for C_d (all of the following subsolutions are included):
    a. Informing consumers about the disposal levy (fee to be paid at the time of purchase as a contribution to the collection and processing costs) and available (existing) collection routes by means of leaflets handed to the consumer at the time of purchase of the product.
    b. Municipalities inform consumers about the opening hours of municipal waste yards and the opportunity to hand in 'small' consumer electronics at those waste yards by means of posters and leaflets that are distributed to all inhabitants of the municipality.
    c. The NVMP informs consumers about all available collection routes and specific pilot projects by means of a dedicated Internet site.
    d. The Dutch Ministry of Spatial Planning, Housing and the Environment informs consumers about all available collection routes and the role of the NVMP/ICT Milieu by means of information on their internet site.
    e. The NVMP informs consumers about the need to hand in 'small' consumer electronics by means of the commercials and posters mentioned under 1a.
    f. Various pilot projects, as discussed in Chapter 4 of this thesis. However, so far these pilot projects have not resulted in nationwide, structural adjustments in the collection routes and accompanying information available to consumers.

This concludes the actual generation of a set of relevant design alternatives (for a bird's-eye view summary, see Table 6.1 on the last page of this Chapter) to be included in the next stage of the design process, i.e. the *evaluation* stage. However, before the next Chapter addresses this topic, this Section needs to consider a possible fourth relevant design alternative (solution) that has been at the centre of attention in many (scientific and societal) discussions with respect to the environmental problems associated with the disposal of used consumer products.

Leasing: a fourth relevant design alternative ?

One design alternative (as a solution for various environmental problems, also with respect to other products than consumer electronics) that keeps getting mentioned by a number of laymen and experts alike is the introduction of leasing as an alternative to selling/buying products. Even though this concept seems rather apocryphal for 'small' consumer electronics such as electrical toothbrushes and electric shavers, for specific other 'small' consumer electronics, such as microwaves and telecommunication equipment (mobile phones), this could actually present a viable alternative. Therefore, this concept certainly deserves mentioning at this point.

The main characteristic of the leasing concept relates to the ownership of the product. Leasing constitutes a relationship between a supplier and a consumer in which the product

remains the property of the supplier (retailer), whereas the consumer is allowed to take the product home and use it in return for a periodical payment.

Assessing this concept from a Triad perspective results in a completely different analysis than the one described above. As a consequence of the fact that the product remains the property of the retailer, the only available collection route for 'small' consumer electronics that are leased to consumers would be the one through the retailers. Generally speaking, the retailer and the consumer will sign a contract that stipulates that the consumer is required to return the product after the agreed upon leasing period. Failing to do so will impose the consumer to pay a fine (that would usually amount to the selling price of a new product). In fact, failing to live up to the contract would make the consumer be liable to legal repercussions. Therefore, in Triad terms, the leasing concept would present a very different point of departure for the separate collection of 'small' consumer electronics.

First of all, the value for O_u and O_d would be significantly different from the situation in which the consumer is the owner of the product. The product is no longer the property of the consumer and he/she signed a contract compelling him/her to return the used product to the retailer after the arranged contract period. Therefore, the consumer, by law, does not have the opportunity to dispose of the used product in any other way than the desired behavioural option of handing the product over to the retailer. Obviously, the values for O_u and O_d subsequently amount to 0 and 1 respectively.

Similar conclusions can be derived for the Triad factors *motivation* and *capacity*. Not living up to the arrangement set out in the leasing contract will result in considerable negative consequences for the consumer, while complying with the stipulations in the contract results in positive consequences. In other words, the values for M_u and M_d amount to 0 and 1 respectively. Furthermore, it would be reasonable to assume that the consumer has signed the contract while having knowledge of the stipulations in that contract, because the retailer obviously is required to inform the consumer of the contents of the contract at the time the contract is agreed upon and signed. Therefore, a lack of knowledge would be unlikely to play a role in the behavioural choice of the consumer.

The above shows that for 'small' consumer electronics that are leased to consumers the T_{scores} for the desirable and the undesirable behavioural alternative are completely different than for products that involve a transfer in ownership. The probability of consumers engaging in inappropriate disposal of used products would be significantly lower for products that remain the property of the retailers. Therefore, if leasing is conceivable for specific products, this concept offers quite a promising (total) solution for enhancing collection rates through retailers, if the retailers subsequently hand these products over to the NVMP/ICT Milieu. However, the fact that the used products are returned to the retailer after the leasing contract expires and not after the product is defective or out of order could constitute a new problem. A number of the returned products will still be operational and therefore represent a value, for instance on the second-hand market. Therefore, it would be quite thinkable that retailers opt to resell the product, for instance to a second-hand dealer, instead of handing over the returned product to the NMVP/ICT Milieu. Obviously, this would represent a situation in which the environmental problem associated with inappropriate disposal of 'small' consumer electronics is not resolved, merely postponed.

The above considerations, especially with respect to the limited applicability of the leasing concept (the range of products for which this concept would be feasible) and the possibility that it only postpones the collection problem, indicate that this solution certainly does not represent a panacea for all collection problems associated with 'small' consumer electronics. Even though it could be argued that this particular solution (conceptual design) certainly deserves a more in-depth analysis, for instance regarding possible means to accommodate with the above-mentioned problems, such an analysis lies beyond the scope of this thesis. Therefore, the remainder of the design effort presented in this thesis focuses on the prevailing situation in practice of a transfer of ownership from the retailer to the consumer at the point of purchase of the product. For this particular situation, this Section has generated three relevant design alternatives (conceptual designs) that form the point of departure for the *evaluation* stage, which is addressed in Chapter 7.

subfunctions	*subsolutions applied within each of the 3 design alternatives*		
	design alternative 1	*design alternative 2*	*design alternative 3*
reduction C_u	education local taxes	education weight-based charging system	information about shared responsibility
reduction O_u	direct feedback	direct feedback	-
reduction M_u	direct feedback local taxes	weight-based charging system	generic education
enhancement O_d	'new' collection points carrier bags	curbside collection mini-containers	limited pilot projects
enhancement M_d	lower 'invoices' lottery tickets	lower 'invoices' direct feedback, present	appeal to voluntary change limited pilot projects
enhancement C_d	information about new measures carrier bags	information about new measures mini-containers	limited information about need to participate and current routes

Table 6.1: A bird's-eye view summary of the three design alternatives

Chapter 7

The evaluation stage

Evaluating the design alternatives for collection rate enhancing measures

7.1 Introduction

The previous Chapter has generated a set of three relevant design alternatives for measures to enhance the collection rates for 'small' consumer electronics in the Netherlands. This set of design alternatives is the starting-point for this Chapter, which describes the *evaluation* stage of the design effort presented in this thesis.

As pointed out by Cross [1994], "an evaluation assesses the overall 'value' or 'utility' of a particular design proposal with respect to the design objectives," and, "the evaluation of alternatives can only be done by considering the objectives that the design is supposed to achieve." Therefore, Section 7.2 reverts to the objectives of the design process in progress, as they have been established in Chapters 1 and 3 of this thesis, in determining the set of research project specific criteria that should be included in the evaluation of the three design alternatives generated in Chapter 6. In addition, this set of criteria is compared with the general (performance) criteria put forward in Section 6.2 and the extent to which this set simultaneously covers these performance criteria is analysed. Based on this analysis, the final set of (performance) criteria for the evaluation stage is determined.

Following this establishment of a set of (performance) criteria, the remainder of this Chapter focuses on evaluating these design alternatives as detailed as possible. Some preliminary conclusions, based on the results of this analysis, are presented in the final Section and represent the point of departure for the next Chapter, which specifically addresses the societal/political feasibility of specific conceptual designs.

7.2 Establishing the final set of (performance) criteria

The set of performance criteria that forms the basis for the evaluation stage of a design process "must be based on the design objectives" [Cross, 1994]. Therefore, establishing the final set of criteria (all criteria that need to be included) requires a re-examination of the objectives that constitute the point of reference for this thesis and the design process it encompasses.

Even though the focus and approach of the research project that forms the basis for this thesis have been adjusted (see Chapter 3), the point of departure for this project remains unchanged from the original objective: To contribute to closing the life cycle of consumer electronics, especially with respect to heavy metals, by developing new concepts for organising and managing the Product Recovery Network for consumer electronics (in the

Netherlands) that could contribute to optimising this network from a business economic and environmental perspective. This objective immediately reveals two (types of) performance criteria that obviously (in the eyes of the formulators) play an important role in judging these new concepts:

1. business economic consequences
2. environmental consequences

As discussed in Chapters 3 and 6, within the framework of this general objective, the design effort presented in this thesis aims at developing measures that need to be incorporated in the existing Product Recovery Network for consumer electronics in practice in order to enhance the collection rates for 'small' consumer electronics. However, the point of departure for the research project as a whole remains the same, and therefore, these measures, and design alternatives for these measures, at least need to be evaluated on the basis of the original (types of) criteria. Consequently, at this point, "some clarification" [Cross, 1994] of these criteria is required.

With respect to the business economic consequences of any 'new' measure that is introduced, it is important to recognise the different origins of specific costs involved. Apart from the costs that can be directly associated with the actual introduction and execution of the set of subsolutions that a specific design alternative encompasses (costs involved with the collection stage of the Product Recovery Network), these measures will also result in additional costs further on in the Product Recovery Network (costs involved with the processing stage). That is to say, if and when these measures prove to be effective, they will result in increased amounts of collected 'small' consumer electronics. Consequently, the introduction of such measures will result in higher costs involved with the actual processing of (the increased amounts of) discarded 'small' consumer electronics.

Regarding the latter 'type' of costs, it is important to revert to the fact that the existing Product Recovery Network was introduced as a result of the Disposal of white and brown goods Decree [Staatsblad 238, 1998]. The contents and implications of this take-back legislation for consumer electronics have been discussed in detail in Chapter 2 of this thesis. However, at this point it is important to recollect one of the key elements of this Decree: Manufacturers or importers shall finance the cycle deficit, the negative balance that occurs when the costs of disposing of a product is higher than the revenue from that disposal. Simultaneously, these manufacturers and importers are allowed to, and in practice the companies resorting under the NVMP actually do, finance these costs through funds raised by means of a disposal levy (the so-called "Verwijderingsbijdrage") that is charged to consumers whenever they buy a product that comes under the Disposal of white and brown goods Decree [Staatsblad 238, 1998]. However, as indicated in Chapter 2, the NVMP indicates that the funds raised by this levy have become "higher than intended and necessary" [PriceWaterhouseCoopers, 2001], especially with respect to 'small' consumer electronics.

Based on all the above, it would be reasonable to postulate that these potentially higher operating costs for the processing stage of the Product Recovery Network, as a result of the introduction of effective collection rate enhancing measures, are the (legal) responsibility of the manufacturers and importers of 'small' consumer electronics. The current funds raised by the disposal levy for consumer electronics coming under the Disposal of white and

brown goods Decree [Staatsblad 238, 1998] give rise to the assumption that these companies are in a good position to bare these costs. Therefore, it would be fair to say that these potentially higher indirect costs involved with the introduction of measures to enhance the collection rates for 'small' consumer electronics should not play a substantial role in judging/evaluating different design alternatives for these measures. On that account, these costs are not included in the set of criteria to be applied in the evaluation process presented in this Chapter. Simultaneously though, a more detailed reflection on the (possibly different) adjudication of this point of departure by the Dutch government and the NVMP/ICT Milieu will be included in Chapter 8, as this clearly represents an aspect that is closely related to the type of (political/market/competition) considerations put forward in the final Section of Chapter 6.

Regarding the first 'type' of costs, these are the direct result of introducing any 'new' measure and, as such, represent the actual running costs involved with any of the design alternatives to be evaluated. The question which parties need to assume the financial burden as a result of these measures can only be answered based on the specific subsolutions that constitute a particular design alternative for these measures. In fact, one of the main weaknesses of the current Product Recovery Network in practice, as it was established in Chapter 2 of this thesis, is that it is unclear which party is responsible for initiating these measures and which party is responsible for the additional costs involved. Even though the NVMP has acted as an initiator of or participant to a number of pilot projects with respect to the collection of 'small' consumer electronics, the Disposal of white and brown goods Decree [Staatsblad 238, 1998] indicates that the separate collection of consumer electronics shall be provided for by local authorities. Simultaneously though, the Dutch government and the NVMP seem to be the parties bearing the costs of any current collection rate enhancing measures that have been introduced in practice as of yet (the combination of subsolutions constituting design alternative 3 put forward in Chapter 6). Therefore, the point of departure for the remainder of this Chapter is that the running costs involved with a particular design alternative serve as one of the performance criteria to be included in the evaluation stage. Considerations with respect to the appropriate party to actually bear this financial burden are discussed in Chapter 8.

With respect to the environmental consequences of any 'new' measure that is introduced, it is important to recognise the original purpose of the Disposal of white and brown goods Decree [Staatsblad 238, 1998]. This Decree aims at resolving the environmental problems that are associated with inappropriate handling of discarded consumer electronics by means of enforcing the separate collection and environmentally sound treatment of these products. Therefore, the higher the collection rates for 'small' consumer electronics that are achieved by introducing a 'new' measure, the higher the direct environmental benefits associated with that particular design alternative.

However, the introduction of collection rate enhancing measures can also result in additional (unwanted) environmental consequences. For instance, higher collection rates result in a higher number of trucks needed to transport the collected consumer electronics from the collection points to the processing facilities. Simultaneously, the weight of regular household waste decreases, which obviously has a reverse effect on the number of trucks needed for the collection and transport of regular household waste. Some other examples of environmental consequences involved with specific subsolutions that constitute a particular design alternative are:

- The distribution of bags/containers to consumers as an aid for storing and transporting/handing over 'small' consumer electronics involves environmental consequences with respect to the production and transportation of these containers.
- Rewarding consumers for handing in 'small' consumer electronics results in either the necessity to produce and transport appropriate presents, or put more money at the disposal of consumers. Obviously, the spending of this money by those consumers will result in a whole new 'chain' of environmental consequences.
- The bags/containers and presents mentioned above constitute a 'new' disposal problem in itself.

This short list of examples of (inter)linked environmental consequences presents an illustration of the complexity of environmental issues. An accurate and complete analysis of all environmental consequences of any action, being it a collection rate enhancing measure or any other event, if at all possible, presents a whole new research field (dilemma) in itself, and certainly lies beyond the scope of this thesis.

Therefore, in line with the ultimate objective of the Disposal of white and brown goods Decree [Staatsblad 238, 1998], the point of departure for the remainder of this Chapter is that the (separate) collection rate for 'small' consumer electronics achieved by any 'new' measure constitutes the environmental performance level of that particular design alternative.

Based on all the above, the following **initial set of two (performance) criteria** should serve as a basis for the evaluation of the design alternatives put forward in Chapter 6:

- The (increase in the) **collection rate for 'small' consumer electronics** that results from the introduction and execution of the set of subsolutions that constitute a particular design alternative.
- The **running costs** involved with the introduction and execution of the set of subsolutions that constitute a particular design alternative.

Obviously, the second (performance) criterion represents a measurement that could be referred to as the *effectiveness* of a particular design alternative and the ratio of the two criteria directly relates to the *efficiency*. Consequently, the two criteria mentioned above sufficiently cover the first two of the general (performance) criteria put forward in Section 6.2 of this thesis. However, the third (performance) criterion mentioned there, i.e. *feasibility* of the specific design alternatives, so far has not been considered in the discussion above. Therefore, the extent to which this aspect gives cause to add a third (or even fourth) criterion to the initial set of criteria mentioned above needs to be examined at this point.

The previous Chapters of this thesis have already touched upon one important element of the feasibility concept, i.e. the societal/political feasibility of collection rate enhancing measures. However, it would be presumptuous to assume that this thesis can provide a completely accurate analysis and especially a completely accurate prediction of the influence of these aspects on the utilisation of the findings in this thesis in practice. Therefore, a more detailed analysis of this part of the feasibility criterion forms the topic of Chapter 8 and, as it were, is excluded from the evaluation stage presented in this Chapter.

Consequently, the societal/political feasibility of specific design alternatives is not expressed in an additional (performance) criterion at this point.

Conversely, another element of the feasibility concept, i.e. the practical feasibility considering current structures and allocations of tasks and responsibilities that need to be adjusted, definitely should be accounted for in the evaluation stage presented in this Chapter. Obviously, a design alternative that is extremely effective and efficient (manifesting itself in a high probability of high collection rates and low running costs) could still prove to be futile, if the set of subsolutions incorporated in that alternative cannot be made to come into operation. The latter touches upon a clear distinction between a design process focusing on a tangible product and a design process focusing on the development of societal measures, as the design process presented in this thesis. Whereas the practical component of feasibility with respect to a tangible product mainly relates to technical feasibility aspects of the design object itself (such as required production processes, tools, material specifications, and so on), the main problem with respect to the practical feasibility of the design object under consideration in this thesis relates to the fact that it needs to be integrated into existing societal, legal, business and organisational structures. Obviously, deciding on the 'best' design alternative to be the subject of the next stage in the design process, constructing the final design by "improving details" [Cross, 1994], requires a full understanding of the possibilities and impossibilities with respect to all relevant aspects of this integration process. Therefore, analysing these aspects needs to be included in the evaluation stage presented in this Chapter. Such an analysis can be represented by adding a **third criterion** to the initial set of two (performance) criteria mentioned above:

- **The extent to which the set of subsolutions** that constitute a particular design alternative **can (easily) be integrated into existing** societal, legal, business and organisational **structures**. In other words, the practical difficulties and obstacles involved with the introduction and execution of this set of subsolutions in practice.

Whereas the initial two criteria represent criteria that can be applied to adjudge the 'performance' of a specific design alternative, this third criterion represents more of a constraint. Evaluating the three design alternatives put forward in Chapter 6 by this third criterion results in more insight with respect to the extent to which a specific design alternative satisfies this important constraint and, as such, forms an essential element of the evaluation stage. In fact, it is quite conceivable that a specific design alternative that scores high on the two initial performance criteria will not be selected for the "improving details" stage of the design process on grounds of a low score for this third criterion (a low suitability of that alternative to be integrated in existing societal, legal, business and organisational structures).

7.3 Comparing the (theoretically) achievable collection rates

This Section compares the three design alternatives put forward in Chapter 6 on the basis of the first performance criterion, i.e. an estimation of the collection rate for 'small' consumer electronics that would result from the introduction and execution of the set of subsolutions that constitute that particular design alternative in practice. As discussed in Chapter 3 of this thesis, apart from the pilot projects discussed in Chapter 4, this estimation cannot be based on any sort of further testing of prototypes. Therefore, the comparison of the three design alternatives is based on the findings in Chapters 4 and 5 of this thesis and a connected Triad analysis [Poiesz, 1995/1999]. Initially, the separate subsolutions for the execution of the six subfunctions that were established in the previous Chapter are discussed and compared for each of the three design alternatives. Subsequently, the resulting collection rates for 'small' consumer electronics to be expected for each of these alternatives as a whole are analysed by means of an overall Triad analysis (i.e. the resulting T_{scores} and the probability of 'balance and spiral effects').

Subsolutions with respect to the reduction of the value for C_u:
Whereas all three design alternatives try to activate a 'sense of guilt' by educating consumers about the environmental consequences related to the inappropriate disposal of 'small' consumer electronics, design alternatives 1 and 2 not only address these consequences in more detail than design alternative 3, they also direct the financial capacity of consumers to engage in the undesirable behavioural alternative. Design alternative 1 applies additional taxes, while the financial component of C_u is addressed as an integral part of a weight-based charging system in design alternative 2. The 'invoice' for inappropriate disposal behaviour in the second system will be based on the weight of the consumer electronics disposed of by means of the refuse bag/bin and the costs (per kilogram) associated with regular household waste collection services. In the first system, the 'invoice' is specifically based on and attributed to the costs associated with the handling of 'small' consumer electronics as an unwanted component of the regular household waste stream. The height of the connected taxes can be established separately from the invoices for regular household waste collection services. Therefore, the choice for a specific tax level determines the actual contribution to reducing the financial capacity of consumers. Based on the additional costs that are caused by the environmental problems associated with 'small' consumer electronics, the choice for a tax level that represents higher 'invoices' per kilogram compared to the 'invoices' per kilogram for regular household waste seems logical. Consequently, the resulting reduction in the value for C_u for design alternative 1 is higher than for design alternative 2. Therefore, all the above can be summarised as follows (Eq. 7.1)[1]:

(7.1) $\quad C_u\,(\mathrm{d1}) < C_u\,(\mathrm{d2}) < C_u\,(\mathrm{d3})$

[1] In Equation 7.1 and all subsequent equations in this Chapter, design alternative 1 is represented by d1, design alternative 2 by d2, and design alternative 3 by d3. Consequently, the expression C_u (dx) refers to the value for C_u that results from the introduction and execution of design alternative x.

Subsolutions with respect to the reduction of the value for O_u:
For design alternatives 1 and 2, similar subsolutions are applied to reduce the opportunity for consumers to feel 'okay' or 'unaware' about their behaviour and the financial consequences. Design alternative 3 lacks a specific subsolution for this subfunction. Therefore, the relation between the resulting values for O_u for the three design alternatives can be expressed as follows (Eq. 7.2):

(7.2) $O_u\,(\mathrm{d1}) \cong O_u\,(\mathrm{d2}) < O_u\,(\mathrm{d3})$

Subsolutions with respect to the reduction of the value for M_u:
Design alternative 1 combines direct feedback to consumers about environmental and financial consequences of their disposal behaviour with actual taxes that are higher (see the discussion under "Subsolutions with respect to the reduction of the value for C_u") than the effect on the invoices that are associated with the weight-based charging system applied in design alternative 2. Therefore, the actual reduction in M_u as a result of applying the subsolutions included in design alternative 1 will be bigger than the reduction in M_u that results from applying the subsolutions that are included in design alternative 2. In contrast, design alternative 3 reverts to activating a 'sense of guilt.' The findings in Chapter 5 of this thesis have indicated that moral costs and benefits (resulting in a specific value for *intrinsic motivation*) constitute weak predictors of environmentally relevant behaviour, whereas actual (tangible) costs and benefits (resulting in a specific value for *extrinsic motivation*) make up strong predictors of this type of behaviour. Therefore, the probable effect on consumer behaviour of the subsolutions applied in design alternatives 1 and 2, that also represent financial consequences, is higher than the probable effect of the subsolution applied in design alternative 3, and can be conveyed by a more significant effect on the resulting value for M_u (Eq. 7.3):

(7.3) $M_u(\mathrm{d1}) < M_u(\mathrm{d2}) < M_u(\mathrm{d3})$

Subsolutions with respect to the enhancement of the value for O_d:
Design alternative 3 incorporates no structural, nationwide subsolutions for this design parameter. Therefore, the value for O_d for the vast majority of consumers will not increase as a result of applying this design alternative. Design alternatives 1 and 2 both include specific subsolutions to enhance the value for O_d for all consumers. Both alternatives result in the distribution of bags/containers that can be used by consumers to store and transport their 'small' consumer electronics to the collection point. The main difference between these two design alternatives lies in the situation of the collection points. The collection points installed by design alternative 1 are situated at supermarkets, whereas the collection points for design alternative 2 are situated at the curbside in front of the consumer's home. Therefore, generally speaking, the first option requires the consumer to transport the products to be handed in over a longer distance than the second option. However, where handing in used products at the supermarket is possible during the full duration of opening hours of these supermarkets (usually 6 days a week, about 12 hours a day), the curbside collection that is integrated in design alternative 2 is typically provided for only once a week (or once every two weeks). Consequently, consumers are required to transport the products over a longer distance in one alternative, but simultaneously, this alternative offers more opportunities (in time) to hand in the products and accordingly requires less effort/time/money from the consumer to store the products. Which of these two options ultimately results in the highest value for O_d remains subject to debate (and could possibly

differ among consumers, based on their personal circumstances). Therefore, all the above can best be summarised as follows (Eq. 7.4):

(7.4) $\{ O_d \text{ (d1) and } O_d \text{ (d2)}\} > O_d \text{ (d3)}$

Subsolutions with respect to the enhancement of the value for M_d:
Whereas design alternative 3 aims at enhancing the value for M_d by means of focusing on the *intrinsic motivation* of consumers (by appealing to environmental awareness and collective responsibility as motivators for a 'voluntary behavioural change'), design alternatives 1 and 2 provide subsolutions that aim at providing *extrinsic motivation*. Obviously, the points of departure that were discussed under "Subsolutions with respect to the reduction of the value for M_u" are also applicable to subsolutions applied for the execution of this particular subfunction. Therefore, the subsolutions that are included in design alternatives 1 and 2 will have a more significant effect on the resulting value for M_d than design alternative 3. For both alternatives, appropriate behaviour will result in positive financial consequences for consumers. However, design alternative 1 encompasses a lottery ticket as a reward for handing in 'small' consumer electronics, whereas design alternative 2 provides consumers with a more symbolic reward. The findings in Chapters 4 and 5 have revealed that the behavioural effect to be expected is higher for the first type of reward, which can be conveyed by a more significant effect on the resulting value for M_d. Therefore, all the above results in the following representation of the effectiveness of the subsolutions included in each of the three design alternatives with respect to the execution of this subfunction (Eq. 7.5):

(7.5) $M_d\text{(d1)} > M_d\text{(d2)} > M_d\text{(d3)}$

Subsolutions with respect to the enhancement of the value for C_d:
Design alternatives 1 and 2 include subsolutions that incorporate more direct communication means and more detailed information (about the available collection routes and rewards) than design alternative 3. Furthermore, the first two alternatives provide consumers with additional aids to engage in the desirable behavioural alternative. Therefore, the increase in the value for C_d as a result of applying the subsolutions included in the alternatives 1 and 2 will be considerably higher than for the subsolutions included in the third design alternative. With respect to the actual messages that are communicated to consumers, both alternatives 1 and 2 propose to inform consumers about the 'new' collection routes and the rewards involved. The main difference lies in the fact that the set-up of design alternative 1 allows for emphasising the reward that consumers can obtain by handing in 'small' consumer electronics and the lottery based reward system boils down to an opportunity to communicate about 'possibly substantial reward.' The latter implies that this reward system makes it (relative to the other design alternatives) easier to 'grasp' the attention of consumers, which constitutes a very important precondition for any design alternative to actually influence habitual behaviour. This possibility connected to design alternative 1 can be conveyed as a more significant effect on the resulting value for C_d, and therefore, all the above can be represented as follows (Eq. 7.6):

(7.6) $C_d\text{(d1)} > C_d\text{(d2)} > C_d\text{(d3)}$

The outcomes of the above comparisons between the separate subsolutions that constitute the three design alternatives can be summarised as follows (Figure 7.1):

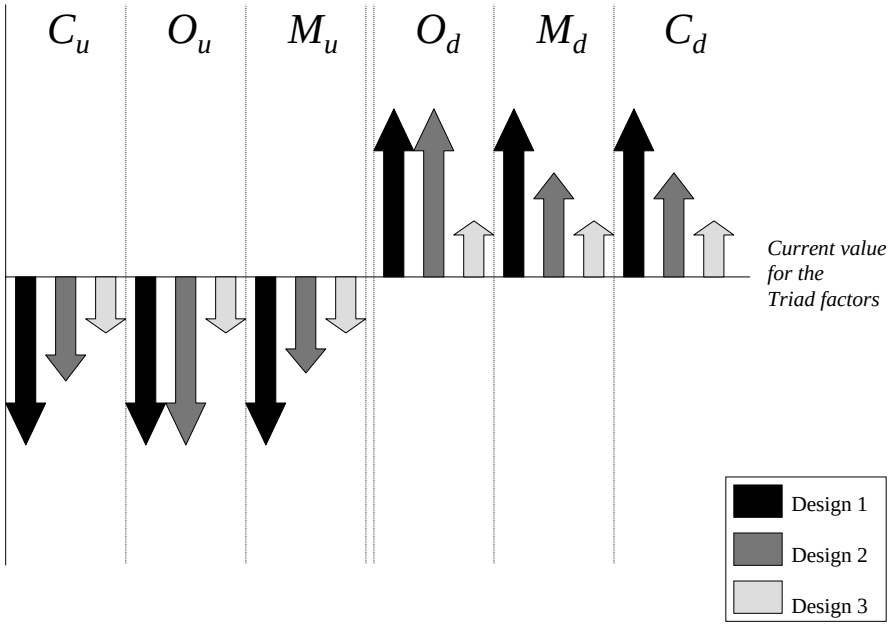


Figure 7.1: A comparison of the effect of the subsolutions included in each of the three design alternatives

In Figure 7.1, the proportions of the arrows do not represent the absolute ratios between the effectiveness of the subsolutions proposed in each of the three design alternatives, however they do represent the ordering of the subsolutions based on their effectiveness. One glance at this figure immediately reveals that the resulting T_{scores} for the undesirable and the desirable behavioural alternatives will be quite different for each of the three design alternatives.

Design alternative 1 incorporates the most effective (set of) subsolution(s) for each of the six subfunctions that need to be executed. In contrast, design alternative 3 incorporates the least effective (set of) subsolution(s) for each of the six subfunctions that need to be executed. Therefore, the resulting T_{scores} for the undesirable and the desirable behavioural alternatives can be expressed as follows (Eq. 7.7, 7.8):

(7.7) $Tscore_u(d1) < Tscore_u(d2) < Tscore_u(d3)$
(7.8) $Tscore_d(d1) > Tscore_d(d2) > Tscore_d(d3)$

Apart from these orders in the resulting T_{scores}, a more general reflection on the main differences between the three design alternatives reveals some additional indications for the overall effectiveness of each of them.

Design alternative 3 incorporates no structural, nationwide subsolutions for enhancing the value of O_d. For many consumers, handing in their used 'small' consumer electronics continues to require them to invest (a lot of) money, time and effort. Therefore, the value for O_d remains very low. Simultaneously, many of these consumers are unaware of the collection routes available to them within the current Product Recovery Network for consumer electronics in practice. Based on the fact that design alternative 3 incorporates only very limited means to resolve this lack of knowledge, the value for C_d remains very low as well. Consequently, the low values for *capacity* and *opportunity* associated with this design alternative result in a low probability of consumers actually engaging in the desirable behavioural alternative. Even if the included subsolutions for enhancing M_d would result in a considerable increase in the *motivation* of consumers to engage in appropriate disposal behaviour, the low values for capacity and opportunity would nullify the ultimate positive effect of these subsolutions, because the T_{score} for this behaviour is based on *motivation∗capacity∗opportunity*. What's more, this situation (low values for *C* and *O*) represents a perfect example of a state of affairs that incorporates a high risk for the occurrence of the so-called 'secondary balance effect.' Consumers that are motivated to engage in the desirable disposal behaviour can easily get discouraged and frustrated by the unfavourable circumstances and faulty communication, subsequently resulting in a lower motivation to look for better circumstances (if available) and to increase their knowledge. Obviously, the ultimate effect will be that the contribution of subsolutions with respect to enhancing M_d are perished and the value for M_d will decrease in the course of time as well.

In contrast, design alternative 1 (and to a somewhat lesser extent design alternative 2 as well) represents effective subsolutions to enhance the values for all three Triad factors with respect to the desirable disposal behaviour. Therefore, this design alternative could very well result in the occurrence of the so-called 'primary balance effect,' which reflects a situation in which the three Triad factors can stimulate each other and an overall T_{score} that increases in the course of time, making consumers actually engaging in that behaviour even more likely. What's more, as indicated above, design alternative 1 incorporates a reward system that makes it easier (relative to the other two design alternatives) to 'grasp' the attention of consumers. This crucial element of design alternative 1 could play a pivotal role in "breaking off environmentally damaging habits" [Van Meegeren, 1997] such as the disposal of 'small' consumer electronics by means of the refuse bag/bin.

Based on all the above, it can be concluded that design alternative 1 represents the set of subsolutions that is the most likely to spur consumers on to reassess the costs/benefits ratios associated with the two behavioural alternatives and to bring about the most substantial actual shift in these ratios in favour of the desirable behavioural alternative. Therefore, **design alternative 1 represents the set of subsolutions that is likely to result in the highest collection rate for 'small' consumer electronics, whereas design alternative 3 represents the set of subsolutions that is likely to result in the lowest collection rate**.

7.4 Comparing the running costs for the three design alternatives

This Section needs to compare the three design alternatives put forward in Chapter 6 on the basis of the second performance criterion, i.e. an estimation of the actual running costs involved with the introduction and execution of the set of subsolutions that constitute a particular design alternative. Once again, as indicated in the previous Section, this estimation cannot be based on any sort of further testing of prototypes. Therefore, this comparison needs to be based on an estimation of the running costs involved with each alternative.

The three design alternatives put forward in the previous Chapter represent so-called conceptual designs, which makes an estimation of the actual costs involved with the introduction and execution of the ultimate detailed design (of the alternative that is chosen for this final step in a design process; also see Section 6.2) in practice extremely difficult.

However, one firm and definite conclusion that can be drawn at this point relates to the clear difference between the current strategies applied by the Dutch government, municipalities and the NVMP/ICT Milieu to enhance collection rates for 'small' consumer electronics (design alternative 3), and the two concrete (design) alternatives proposed by the author of this thesis (design alternatives 1 and 2). All three design alternatives incorporate a set of subsolutions that constitute a so-called 'communication strategy.' Even though the focus of the communication to consumers in each of the three design alternatives is somewhat different and the central message that needs to be communicated varies from one alternative to another, the actual activities that need to be executed within the framework of those 'communication strategies' are very similar. All three design alternatives apply means such as advertisements, leaflets and commercials. Therefore, a somewhat different focus (expressed in the actual contents of the communication to consumers) will have a very limited additional effect on the costs involved with the communication effort included in a particular design alternative.

For design alternative 3, the costs involved with communicating to consumers forms the lion's share of all running costs involved with introducing this alternative, because promotional campaigns constitute the central element of this strategy. In contrast, design alternatives 1 and 2 incorporate a number of additional activities that need to be executed to effectuate the complete set of subsolutions that make up these alternatives. These additional activities contain large-scale efforts such as nationwide distribution of carrier bags or mini-containers, drawing up adjusted invoices, handling of collected (handed in) 'small' consumer electronics either at the supermarket or at the curbside in front of the consumer's home. Therefore, it is obvious that these activities represent substantial additional running costs. Consequently, it can be concluded that **the running costs involved with the introduction and execution of the set of subsolutions that constitute design alternatives 1 and 2 are significantly higher than for design alternative 3**.

As discussed above, comparing design alternatives 1 and 2 relates to comparing two conceptual designs, and therefore, only allows for a rather indistinct analysis. Passing judgement with respect to the running costs involved with these two alternatives involves comparing the costs involved with the additional activities mentioned above.

Both alternatives incorporate subsolutions that relate to providing direct feedback to consumers and taxing/invoicing these consumers. Based on the fact that these activities need to be carried out on the same scale, it would be reasonable to assume that the running costs involved with these activities do not differ substantially. The main differences between these two alternatives are linked with the activities needed to determine the appropriate amounts of those taxes/invoices, the actual collection (points) and the reward system.

Design alternative 1 requires periodical analyses of the contents of representative samples of the regular household waste of groups of consumers (streets, districts, municipalities), whereas design alternative 2 requires the introduction and execution of a weight-based charging system. The latter certainly is not yet widespread among municipalities in the Netherlands and, therefore, would require a substantial investment in organisational measures and the (technical) equipment needed to make such a system come into effect nationwide. Consequently, it would be reasonable to assume that the running costs involved with the activities needed to determine the appropriate amounts of the taxes/invoices are higher for design alternative 2 than for design alternative 1.

The actual collection activities for these two design alternatives are of a different kind completely and, therefore, comparing the costs involved with each of these two approaches based on the conceptual designs presents a problem. However, a provisional analysis of the main differences could give rise to some preliminary conclusions.

Design alternative 1 incorporates the situation of collection points at supermarkets. Based on the fact that supermarkets already act as collection points for ‘deposit money’ bottles, it would be reasonable to assume that the ‘new’ collection points for ‘small’ consumer electronics could be (partially) combined with these existing collection points. Therefore, substantial investments in organisational measures and (technical) equipment needed to make such a system come into effect are probably not required.

In contrast, design alternative 2 requires the development of special garbage trucks, adjustments of existing garbage trucks, or the application of additional collection vehicles to allow for the separate collection of ‘small’ consumer electronics. What’s more, special mini-containers need to be developed, manufactured and distributed. Without engaging in a more detailed analysis of all organisational measures and (technical) equipment that are needed to install and execute/preserve this ‘new’ collection route, it would be reasonable to assume that this would require some substantial investments. Consequently, it can be concluded that the running costs involved with the actual collection of ‘small’ consumer electronics are likely to be higher for design alternative 2 than for design alternative 1.

One specific characteristic that could form an advantage of design alternative 2 is that the garbage trucks will probably be able to collect ‘small’ consumer electronics for bigger groups of consumers than one supermarket. Therefore, the costs involved with handling and transport from the collection points to the point of transfer to the NVMP/ICT Milieu could very well be somewhat lower. However, transporting the collected products by means of the trucks that are applied for the regular provisioning of the supermarkets and locating these transfer points at distribution centres associated with the holding companies of supermarkets could very well resolve this issue. The latter is a clear example of how

"improving details" in the final stage of the design process could have a significant effect on the running costs involved with a particular design alternative.

Another element of design alternative 1 that involves 'extra' costs relates to the reward system applied in this design alternative. Once again, the ultimate costs involved with this reward system depend upon the effectuation in practice. However, it would be reasonable to assume that the costs for a lottery based reward system do not have to be significantly higher than the application of fitting/symbolic presents proposed in design alternative 2.

Based on all the above, the **preliminary conclusion** with respect to a comparison of the two conceptual designs in broad outlines is that **the running costs involved with the introduction and execution of the set of subsolutions that constitute design alternative 2 are likely to be higher than for design alternative 1**.

7.5 Comparing the 'practical feasibility' for the three design alternatives

This Section needs to compare the three design alternatives put forward in Chapter 6 on the basis of the third (performance) criterion, i.e. an estimation of the actual difficulties and obstacles involved with the introduction and execution of the set of subsolutions that constitute a particular design alternative in practice.

The three design alternatives put forward in the previous Chapter represent so-called conceptual designs, which makes a prediction of the actual difficulties and obstacles that will manifest themselves during the effectuation in practice of the ultimate detailed design extremely difficult. In fact, the way a specific conceptual design is worked out into a detailed design and, consequently, the way in which specific details are constructed in practice obviously plays a major part in the likelihood that specific difficulties/obstacles will occur. Simultaneously though, that last notion does provide some starting-points for discussing possibilities and impossibilities associated with the effectuation of these alternatives in practice on a more generic level.

The first conclusion that can be drawn at this point relates to the clear difference between the current strategies applied by the Dutch government, municipalities and the NVMP/ICT Milieu (design alternative 3), and the two concrete (design) alternatives proposed by the author of this thesis (design alternatives 1 and 2). Design alternative 3 has already been effectuated and integrated into existing structures within the framework of the Product Recovery Network for consumer electronics in practice. Therefore, the choice for continuation of this approach in favour of the two new approaches defined in design alternatives 1 and 2 represents the solution that will result in no (new) difficulties. Working out design alternatives 1 and 2 into a detailed design and, consequently, constructing specific details in practice are likely to result in at least some difficulties that need to be overcome (as is illustrated in the remainder of this Section), because they represent an adjustment of the current disposal structure in practice. Therefore, in terms of evaluating all three design alternatives on grounds of this criterion this leads to the preliminary conclusion that **design alternative 3 is likely to result in the least difficulties with respect to effectuating the set of subsolutions that constitute this alternative in practice**.

Comparing design alternatives 1 and 2 relates to comparing the extent to which the ultimate effectuation in practice of the various subsolutions could possibly be integrated (or not) into existing legal, societal, business and organisational structures. For design alternative 1 the possibilities for actual integration certainly seem more obvious than for design alternative 2.

With respect to the actual collection of 'small' consumer electronics, design alternative 1 proposes to locate collection points at supermarkets. These supermarkets already contain a collection point for 'deposit money' bottles, either by means of a special counter or a so-called "retourette" (a conveyer belt combined with an automatic voucher generator). Integrating a collection route for 'small' consumer electronics into this existing structure certainly seems feasible. The counter could be used as a combined collection point for both bottles and 'small' consumer electronics and the "retourette" usually is equipped with an opening for bottle crates that is certainly big enough to also be used for 'small' consumer electronics. The collection system for bottles already involves handing over vouchers to the consumer, so including the handing over of lottery tickets as a reward should not present any significant problems. Additionally, supermarkets in the Netherlands seem to get more and more involved in recent years with the sales of consumer electronics, such as computer equipment and, therefore, are already confronted with the execution of the "old for new" regulations included in the Disposal of white and brown goods Decree [Staatsblad 238, 1998]. Consequently, an extension of these activities to include the subsolutions proposed in design alternative 1 seems unlikely to result in any insurmountable obstacles.

In contrast, design alternative 2 proposes the introduction of a collection route that is combined with the current collection system for regular household waste. However, the effectuation of this design alternative requires some specific adjustments of the current system. The collection of regular household waste has long since been the responsibility of local authorities (see Chapter 2). Most municipalities do not yet apply a weight-based collection system and design alternative 2 would require them to introduce such a system. Therefore, the effectuation of this design alternative would require national authorities to enforce local authorities to introduce such a system. Such an ordinance goes against current (legal and organisational) structures and could result in some significant difficulties or even obstacles.

Furthermore, as indicated in Chapter 2, the majority of municipalities in the Netherlands have transferred responsibility for waste management activities like collection and treatment of household waste to private firms. In most Dutch cities and villages, these firms are now responsible for all waste management activities that used to be the responsibility of municipal waste management services. The introduction of design alternative 2 would require these private firms to accept the additional task of separately collecting 'small' consumer electronics and handing them over to the NVMP/ICT Milieu. Obviously, this change in roles could present some specific difficulties as well, not to mention a clear possibility of these private firms demanding higher compensation and the need for substantial technical adjustments to their equipment (see previous Section).

The actual collection of 'small' consumer electronics in design alternative 2 is executed by means of curbside collection. The mini-containers containing used 'small' electronics are placed by the consumers in front of their home. However, the actual emptying of these mini-containers could take place hours later and, therefore, they could remain outside for a

significant amount of time. Obviously, this could result in some unwanted side effects, such as people opening the mini-containers and appropriating these (environmentally damaging) products for other means than environmentally sound disposal. This problem needs to be dealt with in the "improving details" stage if this alternative would be selected for this next step in the design process and could certainly present a major obstacle in the successful introduction of this design alternative.

All the above does not represent an exhaustive analysis of all possible difficulties and obstacles that could manifest themselves in the effectuation of design alternatives 1 and 2 in practice. However, this first exploration not only reveals some crucial aspects that need to be addressed in the next stage of the design process ("improving details"), it also gives rise to the preliminary conclusion that design alternative 1 is likely to be more easily integrated into existing societal, legal, business and organisational structures than design alternative 2. In other words, **design alternative 1 seems to be more practically feasible than design alternative 2**.

However, at this point it is important to note that design alternative 1 (and design alternative 2 for that matter) requires the co-operation of a number of parties to be effectuated in practice, e.g. supermarkets, carriers connected to these supermarkets and connected to the NVMP/ICT Milieu, the NVMP/ICT Milieu and municipalities. Therefore, the willingness to participate of these 'stakeholders' and possible/available means to influence this willingness certainly need to be accounted for in the final stage of the design process ("improving details"). Even though this final stage of the design effort lies beyond the scope of this particular thesis, some initial thoughts and points of reference with respect to this issue are discussed in more detail in Chapter 8.

7.6 Selecting the 'best' design alternative and establishing the political dilemma

The evaluation of the three design alternatives, as presented in the previous Sections, clearly establishes the 'dilemma' that faces the initiators of any collection rate enhancing measure. Summarising the results of evaluating the design alternatives for each of the three (performance) criteria eventuates in the following overall conclusions:

- Design alternative 3 (the current strategies applied by the Dutch government, municipalities and the NVMP/ICT Milieu to enhance collection rates for 'small' consumer electronics) represents the set of subsolutions that involve the lowest running costs and the least difficulties/obstacles with respect to effectuating this alternative in practice. However, this design alternative is also likely to result in the lowest collection rate for 'small' consumer electronics.
- Design alternatives 1 and 2 represent the sets of subsolutions that involve higher running costs and more difficulties/obstacles with respect to effectuating these alternatives in practice. However, these design alternatives are also likely to result in significantly higher collection rates for 'small' consumer electronics.

In other words, in terms of the (performance) criteria that were established in Section 6.2 and the overall objective of the design process presented in this thesis, design alternatives 1

and 2 are significantly more effective, but represent the sets of subsolutions that involve more costs (efficiency) and are practically less feasible.

With respect to a mutual comparison of design alternatives 1 and 2 the overall conclusion is quite clear: design alternative 1 results in higher collection rates (more effective), less costs (more efficient) and can be more easily integrated into existing structures (more practically feasible).

Therefore, the ultimate 'societal/political dilemma' that follows from the design effort presented in this thesis amounts to a choice between design alternatives 1 and 3. This 'societal/political dilemma' basically signifies a choice between environmental consequences and financial (economic) consequences. This deliberation is discussed in more detail in Chapter 8, within the framework of an analysis dedicated to the societal/political feasibility of the various design alternatives.

However, with respect to providing a maximum contribution to the general objective for the research project that forms the basis for this thesis, the following straightforward conclusion can be advanced:

> *Actually contributing to closing the life cycle for ("small") consumer electronics (beyond the current situation in practice) would be best served by selecting design alternative 1 for the next step in the design process. Simultaneously, the choice for this design alternative signifies the need for additional investments (money and effort) to achieve this objective.*

Chapter 8

Implementing collection rate enhancing measures

8.1 Introduction

The previous Chapters have established and applied a number of theoretical and practical perspectives within the framework of designing measures to enhance the collection rates for 'small' consumer electronics in the Netherlands. Specific design alternatives for such measures have been evaluated on grounds of expected effectiveness (collection rates), efficiency (running costs) and practical feasibility (the extent to which they can be easily effectuated and integrated into existing structures).

This Chapter deals with the actual implementation of the measures that have been designed. With respect to this topic, it is important to recall the specific nature of the subsolutions that have been advanced, such as tax measures and reward systems. In essence, these collection rate enhancing measures amount to specific societal provisions and regulations, which are all part of an overall effort to influence the disposal behaviour of consumers in the required direction to enhance the collection rates for 'small' consumer electronics.

However, the fact that these provisions and regulations might prove to be effective, efficient and practically feasible does not automatically mean that they will actually be introduced in practice. Chapter 2 of this thesis has shown that the functioning of the current Product Recovery Network for consumer electronics largely depends on the moderating role of acceptance of responsibility by consumers. This composition of the current network, combined with the fact that the inappropriate disposal of 'small' appliances makes up a 'habit' that is easier and more inviting and known than the appropriate behavioural alternative, has resulted in low collection rates for this type of products. Obviously, some authorised party will have to initiate the introduction of specific measures, such as the ones developed in this thesis, to resolve this problem. However, the Disposal of white and brown goods Decree [Staatsblad 238, 1998] does not distinctly assign this responsibility to a specific party, other than consumers, involved with the current network. In other words, even though this thesis has shown *how* the collection rates for 'small' consumer electronics could be enhanced, it is not quite clear yet *who* should initiate the effectuation of these measures in practice.

Section 8.2 focuses on this problem by returning to the current Product Recovery Network for consumer electronics in the Netherlands and analysing the current allocation of responsibilities among the parties involved. It specifically addresses the question who is responsible for (promoting) the appropriate (separate) disposal of consumer electronics, which determines the ultimate collection rates.

Subsequently, Section 8.3 focuses on the concept of 'problem-ownership' and, more specifically, the responsibility for an actual decision with respect to (initiating) efforts to

enhance collection rates for ‘small’ consumer electronics and the introduction of specific measures to achieve this objective.

Finally, some specific observations by the author of this thesis with respect to the effectiveness of the Disposal of white and brown goods Decree [Staatsblad 238, 1998] in practice and particularly the effect of current (and future?) positions of involved parties on the feasibility of actually achieving higher collection rates for ‘small’ consumer electronics in the Netherlands conclude this Chapter.

8.2 The current allocation of responsibilities

Chapter 2 of this thesis has explained the origination of the current Product Recovery Network for consumer electronics in the Netherlands in practice, which is the direct result of the Disposal of white and brown goods Decree [Staatsblad 238, 1998] coming into force. This Decree has introduced a number of restrictions and regulations to enforce a ‘leak proof’ disposal structure for consumer electronics. As indicated in Chapter 2, the Decree advocates a fair distribution of tasks and responsibilities among consumers, suppliers, repair companies, local authorities, and producers and importers. To realise this aspiration the Decree allocates specific tasks and responsibilities within this disposal structure to specific parties. In light of the topic of this Chapter it is important to re-establish this allocation of responsibilities.

Within a disposal structure for consumer electronics, the following three main stages can be identified (see Figure 8.1):

1. The actual disposal of end-of-life products
2. The separate collection of these products
3. The processing of these products

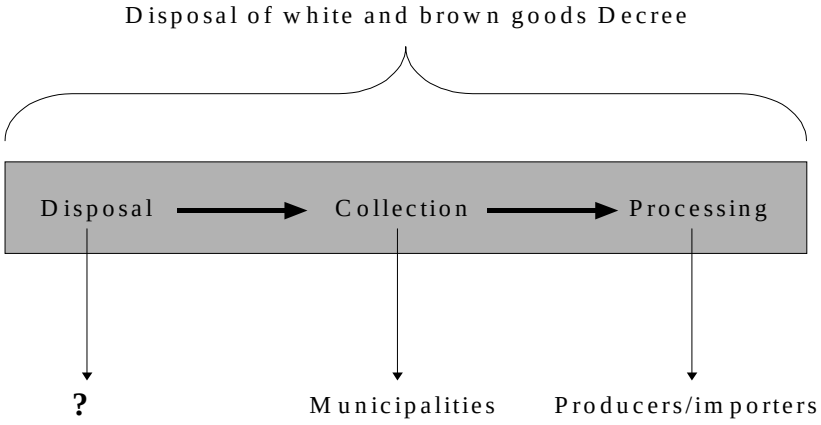


Figure 8.1: Allocation of responsibilities
as a result of the Disposal of white and brown goods Decree

From the analysis presented in Chapter 2 it is clear that the collection of consumer electronics that are set free by consumers is mainly the responsibility of municipalities. They are required to provide for separate collection of consumer electronics originating from private households and the creation and maintenance of a storage facility where suppliers can leave products taken back from consumers. However, this responsibility is defined in 'qualitative' terms and not by means of setting targets for the specific collection rates that need to be achieved. In other words, this responsibility quite specifically focuses on providing separate collection routes for products that are actually offered for collection (set free) by consumers, not on influencing the number of products that is offered for collection by these consumers. Therefore, within the framework of the current Product Recovery Network for consumer electronics, municipalities cannot be (and are not) hold accountable for the ultimate collection rates that are achieved.

The processing of the products that are actually collected separately is the responsibility of producers and importers, represented by the NVMP/ICT Milieu[1]. They are responsible for taking in all consumer electronics handed over to them by municipalities and the environmentally sound processing of these products. They are not responsible for the number of products handed over to them by these municipalities and, consequently, they too cannot be (and are not) hold accountable for the ultimate collection rates that are achieved, a reference point that is repeatedly stressed by the parties involved (see e.g. [PriceWaterhouseCoopers, 1999] and [PriceWaterhouseCoopers, 2001]).

All this means that the actual appropriate disposal of consumer electronics, and the resulting collecting rates, is not the responsibility of these two main parties involved with the current Product Recovery Network for consumer electronics in the Netherlands. In fact, one could even argue that it is not in their best interest to promote appropriate disposal behaviour and consequently higher collection rates, because that would result in higher workloads and working expenses, while not resulting in any clear rewards or advantages (see Chapter 2).

The third main party involved in the current disposal structure for consumer electronics is 'the consumer.' The Triad analysis presented in Chapter 5 shows that it would be unrealistically optimistic to expect this party to assume the responsibility for the actual collection rates that are achieved by the current system,' especially with respect to 'small' appliances. In fact, from the analysis presented in this thesis it is quite apparent that the current system incorporates no mechanisms to prevent them from persisting in their long since habit of throwing particularly 'small' consumer electronics in the refuse bag/bin.

All the above, once again, shows that the functioning of the current system largely depends on the moderating role of acceptance of responsibility by consumers and that this constitutes one of the main reasons for the current low collection rates for 'small' consumer

[1] An important observation with respect to this 'representation' is that the current system eliminates one of the most important mainsprings for companies to strive for environmentally sound solutions and innovations in this area. Whereas in other market segments striving for a 'green image' can provide a competitive advantage, the fact that in the current disposal structure for consumer electronics the responsibilities of companies in this area are transferred to the NVMP and ICT Milieu implies that this motive has lost its relevancy.

electronics. The current way in which the Disposal of white and brown goods Decree [Staatsblad 238, 1998] has assigned responsibilities has resulted in a Product Recovery Network that does not incorporate mechanisms to influence consumer behaviour in the required direction (handing in consumer electronics by means of separate collection routes) and a network that does not incorporate a clear assignment of responsibility to solve this problem (see Figure 8.1).

Obviously, this observation presents a complicating factor with respect to the collection rate enhancing measures that have been developed in this thesis. These measures could provide a solution to the problem described above, introducing mechanisms to influence consumer behaviour in the required direction, but it is unclear who should be considered to be the 'proper' party to act as initiator for the effectuation of these solutions in practice. From all the above, it can be concluded that it would be unrealistically optimistic to expect municipalities and/or producers and importers to act as leaders in this process. Therefore, the next Section addresses this dilemma in some more detail, analysing who should be considered as the ultimate 'problem-owner' and consequently as the 'proper decision-maker.'

8.3 Problem-ownership/decision making: initiating specific measures

The previous Chapters of this thesis have unfolded a design process in an effort to develop appropriate measures to enhance the collection rates for 'small' consumer electronics in the Netherlands. The decision to engage in such an effort was based on the wish to make a maximum contribution to the overall objective for this research project (and three associated research projects; see Chapter 2), i.e. to contribute to closing the life cycle of consumer electronics. This overall objective obviously served as a reference point for this thesis, however, at this point, it is important to analyse the origin of this objective in some more detail. In other words, this objective presupposes a problem that 'needs' to be solved and in order to analyse the political and societal feasibility of actually introducing specific solutions for this problem it is important to (re-)establish both the 'problem-owner' and the 'decision-maker' with respect to effectuating these solutions in practice. This has become even more important now that the previous Section has established that the current Product Recovery Network for consumer electronics in the Netherlands lacks a clear assignment of responsibility with respect to resolving the faltering collection stage within this network.

An approach to achieve this would be to establish the initiators of the research project that formed the basis for this thesis and subsequently conclude that they obviously represent the 'problem-owners' and 'decision-makers' with respect to the underlying problem. In this case, the research project is part of a so-called IOP-project. These IOP-projects represent groupings of research projects, dedicated to a specific theme, that are both approved and sponsored by the Dutch government. Therefore, it would be reasonable to assume that the Dutch government represents the factual 'problem-owner' with respect to the problem that has been addressed in this thesis and should play a pivotal role in the decision process regarding the ultimate effectuation in practice of proposed solutions.

An alternative approach to establish the 'problem-owner' and 'decision-maker' with respect to the topic of this thesis would be to analyse the background of the problem itself. Chapter 2 of this thesis already indicated that the ways in which discarded consumer electronics in

the Netherlands were disposed of in the years before 1999 resulted in some specific environmental problems. In an attempt to eliminate these problems, Dutch authorities launched a number of consultations with interested parties on the topic of appropriate disposal systems for consumer electronics. However, these deliberations failed to provide sufficient points of departure to install an effective disposal system for these appliances. All this resulted in Dutch authorities to conclude that the only adequate way of tackling this problem was by means of legislation, ultimately leading to the formulation and introduction of the Disposal of white and brown goods Decree [Staatsblad 238, 1998]. The general objective of this Decree was to enforce a 'leak proof' disposal structure for consumer electronics. However, Chapter 2 of this thesis has indicated that the actual disposal structure in practice that has emerged as a result of this Decree functions less than perfect, especially with respect to 'small' consumer electronics. Therefore, the current situation in practice differs from the objective of the Dutch government, as it was defined in this Decree. Consequently, this difference represents a problem for the party that defined the original objective; the Dutch government is the 'problem-owner.' In line with this observation, the Dutch government also represents the 'decision-maker' with respect to effectuating possible solutions to eliminate (part of) this difference, such as the solution(s) proposed in this thesis.

One could argue that this analysis should be taken even one step further by addressing the problems that formed the initial reason for the deliberations and consequent legal actions by the Dutch government mentioned above. These problems (as a result of inappropriate handling of discarded consumer electronics) represent so-called 'environmental problems.' These environmental problems relate to the "substantial health risk" [Staatsblad 238, 1998] that results from the (unwanted) dispersion (and squandering) of hazardous substances and materials, such as bromide, arsenic, copper, chromium, mercury, lead, nickel, cadmium and PCBs. Obviously, these health risks are not and can not be contained to a specific group of people in the Netherlands and, therefore, represent a so-called 'public health risk.' In other words, the 'problem-owner' of the environmental problems that are caused by inappropriate handling of 'small' consumer electronics, e.g. disposal of these products by means of the refuse bag/bin, is the public, or the (Dutch) society as a whole. This observation immediately relates to the concept of social dilemmas, as it has been discussed previously in this thesis. From the analysis in this thesis it is quite apparent that, even though individual consumers represent the ultimate 'problem-owners' for these environmental problems, the ultimate solutions with respect to enhancing the collection rates for 'small' consumer electronics are highly unlikely to arise from autonomous initiatives by this group. In fact, environmental problems represent a prime example of problems that, because of their 'social dilemma character,' need to be addressed by the government as a representative of and on behalf of the entire population of a country. In the Netherlands, the Dutch government certainly deems the tackling of this type of problems to be part of its assignment and objectives. This can be illustrated by, among other things, referring to the origination of the Disposal of white and brown goods Decree ([Staatsblad 238, 1998], see above and Chapter 2 of this thesis) and the mission statement of the Dutch Ministry of Housing, Spatial Planning and the Environment (VROM): "The care for a sustainable quality of the (living) environment" [VROM, 2002]. The Ministry of VROM explains this mission statement by indicating that it considers it to be one of her tasks to "provide conditions that ensure the quality of living in our present and future society." Therefore, it would be fair to conclude that, without ignoring the responsibility of individual consumers, the Dutch government is responsible for providing the conditions to ensure that the

"substantial health risks" associated with inappropriate disposal of 'small' consumer electronics are eliminated. Consequently, once again, the ultimate 'problem-owner' and 'decision-maker' with respect to (possible solutions for) this type of problems is the Dutch government, possibly more specifically the Ministry of Housing, Spatial Planning and the Environment.
From all the above, it can be concluded that the Dutch government represents the party that should be considered to form the 'problem-owner' with respect to the environmental problems associated with a 'non-leak proof' disposal structure for consumer electronics. Furthermore, it would be reasonable to conclude, also as a consequence of not (yet) assigning this responsibility to other parties involved (see previous Section), that the Dutch government also represents the 'proper decision-maker' with respect to initiating solutions that could eliminate (part of) these problems, such as collection rate enhancing measures for 'small' consumer electronics.

A final reason for allotting full responsibility for the introduction of collection rate enhancing measures to the Dutch government is related to the contents of these measures. This thesis has resulted in a proposal that incorporates the introduction of a 'new' collection route, combined with specific communication efforts, a reward system and tax measures (design alternative 1, see Chapter 6) as a possibly effective and efficient way to shape these measures. For this proposal to be effective with respect to collection rates for 'small' consumer electronics in the Netherlands as a whole, these measures need to be introduced on a nation-wide scale. Therefore, also based on all the above-mentioned observations, the effectuation in practice of this solution (or similar alternatives, such as design alternative 2 put forward in Chapter 6) clearly depends upon the Dutch government accepting its own responsibility as 'problem-owner' and 'decision-maker.'

As a relativisation of the role of the Dutch government, without trivialising its responsibility as explained above, it is important to note at this point that the decision to initiate (the "improving details" stage for) the introduction of specific measures is not the end of the line. In fact, as mentioned in previous Chapters, the effectuation of specific measures to enhance collection rates for 'small' consumer electronics requires the co-operation of a number of (non-governmental) parties.

The above can be illustrated by referring to design alternative 1 (see Chapters 6 and 7) as an example of a measure that needs to be introduced in practice. This design alternative requires an active involvement of:

- supermarkets, that act as collection point and that need to reward consumers for their participation,
- carriers that are connected to these supermarkets, that could transport collected appliances to a transfer point (for instance the regional Distribution Centre (DC) of the mother company), where the products are handed over to the carrier of the NVMP/ICT Milieu,
- carriers that are connected to the NVMP/ICT Milieu, that need to collect these products at these DCs and transport them to the processing facilities,
- the NVMP/ICT Milieu, that need to instruct those carriers to do so, and finally,
- municipalities, that need to adjust their taxes for waste collection services.

Obviously, for some of these parties the willingness to participate in the effectuation of this measure is more logical than for others.

For instance, with respect to the carriers that are connected to the NVMP/ICT Milieu, it would be reasonable to assume that they will not object to a different route, as long as they are paid for their (additional) services.

For the NVMP/ICT Milieu, the situation is a little more complex. The Disposal of white and brown goods Decree requires them to take back consumer electronics that have been collected by municipalities. However, within the framework of this particular collection rate enhancing measure (design alternative 1), used consumer electronics are now collected at supermarkets and need to be transferred to the carrier of the NVMP/ICT Milieu at those individual supermarkets or the DC of the mother company. Even though one could argue that this situation does not represent a significantly different position for the NVMP/ICT Milieu than the current transfer of collected products at Regional Storage Stations, it is certainly not a foregone conclusion that the NMVP/ICT Milieu will agree to these new transfer points, considering their position with respect to pilot projects in the past (see Chapter 4) and the fact that higher collection rates would result in higher workloads and working expenses (see previous Section). An important reference point for convincing the NVMP/ICT Milieu to participate in this collection route could be that specific 'small' consumer electronics, such as mobile phones, represent a positive value in the end-of-life stage [Ansems & Van Gijlswijk, 2002] and this collection route offers a far more promising approach to actually collecting these products than the collection routes currently applied in practice. Higher collection rates for those specific types of products (and resulting revenues) could very well minimise the additional working expenses needed for all collected products. What's more, higher collection rates could also very well play a pivotal role in effectuating more profitable treatment processes, that up to now have not been realised due to insufficient economies of scale.

Finally, the supermarkets that need to start acting as collection points and reward consumers by means of handing out lottery tickets represent a completely different 'stakeholder' than the ones mentioned above. Supermarkets have as of yet not been involved in the Product Recovery Network for consumer electronics in the Netherlands. What's more, current legislation does not in any way require them to co-operate in the effectuation of collection rate enhancing measures. Therefore, they (or their representing bodies) need to be convinced to participate; clearly, this could require remunerating additional costs, or at least, convincing them of the (financial) benefits (e.g. appeal to new customers) that could result from participating in such a collection route.

Obviously, the above does not represent an exhaustive analysis of all possible difficulties and possibilities that need to be considered in the "improving details" stage of the design process that has been initiated in this thesis. As a direct result of its responsibility with respect to initiating collection rate enhancing measures, the Dutch government will have to play a pivotal role in 'convincing' various 'stakeholders' to participate in the effectuation of these measures. Obviously, it would be rather shortsighted to expect that all problems can be resolved by means of additional legislation, also based on the fact that Dutch legislation will have to comply with European take-back legislation to be introduced in years to come. The above has already indicated some other aspects that could contribute to influencing the willingness of these parties. In light of the analysis presented in this thesis however, it is

also important to note that 'convincing' these parties to co-operate represents a problem that is quite similar to the one that was addressed in this thesis, i.e. 'convincing' consumers to participate in the collection of 'small' consumer electronics. Therefore, it would be reasonable to assume that the approach that was applied in this thesis to design appropriate solutions (measures) encompasses a number of reference points for resolving this issue as well.

Consequently, all the above and the contents of this thesis could possibly assist the Dutch government, not only in its role as 'decision-maker,' but also in its role as 'watchman' and "captain" [Mallen, 1970 (reprinted 1996)] of the Product Recovery Network for consumer electronics in the Netherlands. It is apparent that closing the life cycle for ('small') consumer electronics not only requires influencing consumer behaviour, but also stimulating the various parties involved with the disposal structure for these products to facilitate and contribute to achieving this objective. The Dutch government appears to constitute the most appropriate "captain" to lead this process.

8.4 Societal/political feasibility: concluding remarks and discussion

This thesis has provided a critical analysis of the current Product Recovery Network for consumer electronics in the Netherlands. It has also advanced some reference points and a concrete proposal for the introduction of collection rate enhancing measures, specifically with respect to 'small' appliances. Finally, the previous Sections have established the clear responsibility of the Dutch government with respect to the initiation (decision-making and management) of actual effectuation in practice of the findings in this thesis. However, even if the Dutch government has accepted, or will accept, this responsibility, that fact alone does not necessarily mean that specific measures will actually be introduced. The decision to do so is subject to deliberations that go beyond a scientific analysis and redesign of the current system. This final Section provides some thoughts on the possible backgrounds of these deliberations, which could serve as reference points for further discussions:

The Disposal of white and brown goods Decree [Staatsblad 238, 1998] has come into effect as of January 1st 1999. The set of regulations and provisions put forward by this Decree have ultimately resulted in the introduction of the Product Recovery Network for consumer electronics, as it can be found in practice today. The functioning of this network, especially with respect to the separate collection of consumer electronics, depends to a large extent on the acceptance of responsibility by consumers and a subsequent internal motivation to engage in appropriate disposal behaviour. Unfortunately, current collection rates show that this system falters, especially with respect to the separate collection of 'small' consumer electronics.

This problem has been identified, not only by the author of this thesis, but also by various other authors and institutions. For instance, the representative of the Ministry of Housing, Spatial Planning and the Environment (VROM) in the board of experts supporting the research project that formed the basis for this thesis only recently issued a report on the functioning of the current system. That report concludes that "the collection of 'small' appliances could be enhanced (...)" [Veerman, 2002]. It indicates that even within this category some 'bigger' appliances, such as microwaves and vacuum cleaners, form the majority of collected products. Further on, it concludes that "even though some extensive

promotional campaigns by the NVMP specifically focused on the collection of 'small' appliances, the disposal behaviour of consumers could <still> be improved significantly" [Veerman, 2002]. A similar conclusion can be found in the latest progress report of the NVMP to the Ministry of VROM [Stichting NVMP, 2002]. In fact, the conclusion that consumers seem to persist in their long since habit of disposing of 'small' consumer electronics by means of the refuse bag/bin has constituted the mainspring for the majority of pilot projects (in recent years) that specifically focused on the collection of this product category. Therefore, even though this thesis provides a more detailed analysis of this problem and advances possible solutions, the faltering of the current disposal structure with respect to the separate collection of 'small' consumer electronics does not represent a 'new' or 'unknown' problem.

An interesting observation with respect to the pilot projects mentioned above is that even though some of them have shown some very encouraging results with respect to the achieved collection rates, only one of them (the school-based collection system) has resulted in a follow-up project and none of them has resulted in nation-wide (governmental) measures to enhance collection rates for 'small' consumer electronics.

Apart from the school-based collection system, which only runs in limited time spans and reaches only a portion of Dutch consumers, the NVMP has focused its efforts with respect to the enhancement of collection rates on promotional campaigns. The limited effectiveness of such an approach has been addressed extensively in this thesis and the recent conclusions by Veerman [2002] and the NVMP [2002] mentioned above only seem to corroborate this point.

One could argue that the NVMP (and similarly ICT Milieu) is not to blame for this seemingly ineffective strategy applied to solve the problem with respect to the separate collection of 'small' consumer electronics. The Disposal of white and brown goods Decree [Staatsblad 238, 1998] clearly indicates that solving this problem is not the NVMP's responsibility and, given the analysis presented in this thesis, it may not even be in their best interest.

For the Dutch government however, this argument certainly does not apply. In a recently published Waste Control Plan [VROM, 2002] that lays down the waste policy of the Dutch government for the next ten years, once again, the objective to establish a 'leak proof' disposal structure for consumer electronics is advanced. However, this Waste Control Plan lacks any specific measures to tackle the problem with respect to the separate collection of 'small' consumer electronics other than the ones already fixed by the Disposal of white and brown goods Decree [Staatsblad 238, 1998]. In fact, another recently published policy note, the National Environmental Policy Plan 4 [the Dutch government, 2001], with an even broader policy horizon of 30 years, even states with respect to waste control that "despite a significant increase in the waste volume, the problems are largely controllable."

The above presents a remarkable contradiction. On the one hand the Dutch government, as 'problem-owner,' re-advances the objective to realise a 'leak proof' disposal structure for consumer electronics, and on the other hand that same government, as 'decision-maker,' as of yet has not advanced any solutions for problems, such as the faltering separate collection of 'small' consumer electronics, that hinder the actual realisation of that objective. One might argue that it seems somewhat illogical for a 'problem-owner' that

apparently is aware of specific problems, not to apply the results of successful pilot projects in this field, many of them actually initiated by that same government, in introducing nation-wide measures to resolve these issues.

A possible explanation for this contradiction could be related to the following point of departure that has been laid down by that same government in the above-mentioned Waste Control Plan [VROM, 2002]: "The possible additional costs of source separation and subsequent separate collection <for specific types of waste> need to be socially acceptable and proportional to the environmental gains."
Combining this point of departure with the current situation, as it has been characterised above, one could argue that obviously the Dutch government deems the additional costs of source separation and subsequent collection socially unacceptable or disproportional to the environmental gains.

For instance, the alternative collection route for 'small' consumer electronics that was proposed in the previous Chapters of this thesis does in fact result in additional running costs in comparison to the current strategies applied to encourage appropriate disposal behaviour by consumers. However, at the same time this alternative collection route is very likely to result in higher amounts of separately collected 'small' consumer electronics and, therefore, the amounts of regular household waste will decrease. Consequently, this collection route results in cost reductions for municipalities. What's more, the introduction of this alternative (or other effective alternatives) will result in a considerably lower portion of 'small' consumer electronics in the waste stream that is handled in incineration facilities. Obviously, this results in environmental gains and a completely 'new' costs/benefits ratio, because "MSWI bottom ash may no longer fall into the outdoor category of the Building Materials (Soil and Surface Waters Protection) Decree (Bouwstoffenbesluit bodem- en oppervlakte-waterbescherming), so that additional environmental precautions for their use will no longer be necessary and sales in the long term are assured" [Staatsblad 238, 1998]. In other words, the costs involved with handling the bottom ash and fly ash coming out of incineration facilities could be reduced considerably and some additional revenues could be created. In light of these observations, it is quite remarkable that many of the pilot projects mentioned in Chapter 4 of this thesis have been brought to an end and not resulted in any (nation-wide) follow-up on grounds of a financial analysis that has not taken these aspect into consideration, even though the party that is responsible for such overall costs/benefits analyses (the Dutch government) was either the initiator of or at least involved with most of these projects.

Another deliberation that could possibly result in the Dutch government deeming the additional costs "socially unacceptable" [VROM, 2002] deals with the costs involved for importers and producers of consumer electronics. Higher collection rates for 'small' consumer electronics, that would result from introducing measures as proposed in this thesis, would result in higher costs involved with the processing of separately collected consumer electronics. Even though the NVMP currently commands funds for this type of activities that are "higher than intended and necessary" [PriceWaterhouseCoopers, 2001], one could argue that in the long run these costs will have to be included in the selling prices (as prescribed in EU regulations that will come into effect in years to come). Higher selling prices could result in lower sales and, therefore, could have a negative effect on the market positions of importers and producers of consumer electronics. However, one could also argue that the above-mentioned funds and the fact that the EU is allowing the

Netherlands to continue the disposal levy system (the fee charged to the consumer at the time of purchase of consumer electronics) for ten more years offers an excellent opportunity to minimise the additional costs for importers and producers in the near future. In other words, this jumping-off point would give them time to invest in design efforts to ensure that consumer electronics incorporate less heavy metals and other environmentally damaging substances and more efficient processing techniques, thereby reducing the costs involved with processing these products in the long run.

The above-mentioned arguments represent just a few of the deliberations that could explain (part of) the reluctance of the Dutch government (as of yet) with respect to straightening out the faltering collection system for 'small' consumer electronics.

Even though some, if not all, of these deliberations could be deemed quite logical from an economical perspective, from the perspective of consumers the current position of the Dutch government certainly represents a paradox. Whatever the reasons behind it, as of yet the Dutch government obviously is reluctant to invest (its own and companies') money, time and effort in collection rate enhancing measures such as the ones proposed in this thesis, while these measures could actually not only reward consumers for appropriate behaviour, but could also significantly reduce the amount of money, time and effort that is required from these consumers to engage in that behaviour.

Simultaneously, that same government continues to communicate that they strive for a 'leak proof' disposal structure for consumer electronics and continues to appeal to the 'responsibility' of consumers as the main solution to solve the environmental problems associated with these products. The slogans "The society, you are the society" and "Recycling cannot be done without you" are still applied as the main means to encourage consumers to hand in their used appliances. With respect to this choice, it is important to recall the observation, mentioned in Chapter 2 of this thesis, that general interest in environmental issues and environmental awareness (willingness to invest time, money and effort) of consumers is certainly not rising and is lower nowadays than it was before. Obviously, this observation means that it is at least remarkable that the Dutch government continues to strive for a 'leak proof' disposal system by appealing to "internal motivation" as the main instigation for appropriate behaviour.

Lastly however, one could also argue that the analysis presented in this thesis (demonstrating the importance of simultaneously addressing "external motivation" and barriers to engage in specific behaviour) and the paradox described above (a 'problem-owner' that is reluctant to invest time, effort and money, while continuing to require consumers to invest their time, effort and money) indicate a more profound dilemma. The current set-up of the Product Recovery Network for consumer electronics and the position of the Dutch government could very well perpetuate current "environmentally damaging habits" [Van Meegeren, 1997] of consumers, thereby making it even more difficult to solve associated environmental problems in the long run.

Chapter 9

Conclusions and recommendations

9.1 Introduction

This Chapter winds up the analysis presented in this thesis. Section 9.2 presents the main conclusions as part of a bird's-eye view summary of all the foregoing. Subsequently, Section 9.3 advances some possible reference points for future research and discussions.

9.2 Main conclusions

The amount of waste (in weight) caused by consumer electronics is relatively small compared to some other waste categories, such as regular household waste. However, inappropriate handling of discarded consumer electronics can cause serious environmental problems. Some products contain CFCs and HCFCs, which can cause problems with respect to the ozone layer, while others contain heavy metals that constitute a substantial health risk if they end up in the environment.

To resolve these problems, the Dutch government introduced the Disposal of white and brown goods Decree, that came into effect as of January 1st 1999 and formulates a number of restrictions and regulations to enforce a 'leak proof' disposal structure for consumer electronics in the Netherlands. The key elements of this Decree are that municipalities have to provide for separate collection of consumer electronics originating from private households and producers and importers have to take back those products from municipalities and process them in an environmentally sound manner. The producers and importers were allowed to form an organisation to perform these duties on their behalf. In practice, this has resulted in two specific take back systems, one for ICT equipment and one for all other products coming under the Decree. However, in the course of time these two systems have been integrated for the most part, except for the way in which the cycle deficit is financed. For ICT equipment the costs are financed through invoicing the individual producers and importers, while for the remaining products the costs are financed through funds raised by means of a disposal levy, charged to consumers at the time of purchase of the product.

With respect to the actual disposal behaviour of consumers, which determines the collection rates that can be achieved, the functioning of the current disposal structure largely depends on the moderating role of acceptance of responsibility by consumers and a subsequent internal motivation to engage in appropriate behaviour. Unfortunately, general interest in environmental issues and willingness to invest time, effort and money for general environmental benefits is at a historic low right now and reflects no tendency to increase in the near future. This poses a serious problem for a disposal structure that requires consumers to invest time, money and effort to hand over their used products to the proper

authorities for separate collection. In fact, within the current system inappropriate disposal behaviour, such as disposal of 'small' appliances by means of the refuse bag/bin, is easier (less barriers with respect to required efforts, time and money), more rewarding (relieve from the burden of having to store and transport the products with no negative consequences) and far more generally known than the appropriate alternative (handing products over to the proper collection authorities).

This state of affairs has resulted in low collection rates for consumer electronics, especially with respect to 'small' appliances. Consumers have persisted in their long since habit of throwing these appliances in the refuse bag/bin, which means that they end up in processing facilities for regular household waste. As a consequence, it can be concluded that the current disposal structure for consumer electronics in the Netherlands is not 'leak proof' and that this results in the continuation of the environmental problems that this system was supposed to resolve, especially since a considerable portion of these problems are associated with the inappropriate processing of 'small' appliances.

Unfortunately, the allocation of responsibilities that has been fixed by means of the Disposal of white and brown goods Decree does not clearly attribute the responsibility for resolving this situation to any of the parties involved with the current disposal structure in practice. In fact, one could argue that for the two main parties within this system, municipalities and producers/importers, it would not be in their best interest to promote appropriate disposal behaviour by consumers, resulting in higher collection rates. That would only increase their workloads and working expenses, while not resulting in any clear advantages.

Therefore, it can be concluded that enhancing the collection rates for 'small' consumer electronics, a requirement for the separate and environmentally sound processing of these products, depends upon the Dutch government taking additional measures. For these measures to effective, they need to discourage the inappropriate disposal behaviour and promote the appropriate alternative. In essence, this amounts to introducing societal provisions and regulations that effectively make separately handing over 'small' appliances to the proper authorities easier (less money, time and effort required) and more rewarding than disposal by means of the refuse bag/bin, and this 'new' situation needs to be generally known to consumers.

An effective approach to realise this objective has been advanced in this thesis and would, among other things, include the introduction of the following provisions and regulations:

- Adjusting local taxes based on the amount of ‘small’ consumer electronics detected in regular household waste.
- Direct feedback to consumers about the environmental and financial consequences (taxes) of their disposal behaviour.
- Situating collection points for ‘small’ consumer electronics at supermarkets, analogous to the already existing collection points for ‘deposit money’ bottles.
- Distributing special carrier bags to store and transport these appliances.
- Introducing a lottery based reward system.
- Extensive promotional campaigns that emphasise the rewards and increased convenience.

This approach represents a set of provisions and regulations that require the Dutch government to invest more time, money and effort than they currently invest to promote appropriate disposal behaviour by consumers. Simultaneously, this approach is significantly more effective in enhancing the collection rates for ‘small’ consumer electronics than the current strategies applied by the Dutch government (mainly promotional campaigns, addressing the responsibility of individual consumers). This contrast establishes the dilemma that is facing the Dutch government with respect to ‘small’ consumer electronics; the ultimate decision with respect to actually taking additional measures signifies a choice between environmental and financial consequences.

9.3 Future research and discussions

Obviously, the (political and societal) deliberations with respect to the dilemma described above will have a decisive influence on the appropriate next step following the analysis presented in this thesis. The previous Chapter has advanced some reference points for further discussions on this topic.

If and when it is decided that it would be desirable to apply the findings in this thesis by means of introducing specific collection rate enhancing measures, the proposal for a set of effective, efficient and practically feasible subsolutions, as it has been advanced in this thesis, could constitute the starting-point for subsequent actions. This proposal incorporates a conceptual design, which needs to be worked out into a detailed design. Some specific aspects, among others, that at least need to be included in this "improving details" stage are:

- The exact arrangement of the collection points in supermarkets: for instance, analysing the possibility of adjusting existing "retourettes" so that they can be used for the collection of 'small' consumer electronics.
- The exact arrangement of the tax measures: for instance, analysing the optimal time span that this measure is needed and effective, specifically addressing the risk of this measure evolving into a 'de-motivating' factor in the course of time.
- The exact arrangement of the reward system: for instance, analysing the possibilities to apply existing lotteries/lottery tickets.

If and when it is decided that it would not be desirable to apply the findings in this thesis, it would at least be sensible to pay attention to the usefulness and risks of continuing the current strategies applied to promote collection rates. Some important questions that certainly deserve further attention are:

- Would it be reasonable and wise for the Dutch government to continue to appeal to the 'own responsibility' of consumers?
- Would it be reasonable and wise for the Dutch government to continue to communicate the objective to achieve a 'leak proof' disposal structure for consumer electronics?

The previous Chapter has advanced some reference points for further discussions on these topics.

The analysis in this thesis has shown that the appropriate functioning of the collection stage within the Product Recovery Network for consumer electronics in the Netherlands is not a given. The collection rates that can be achieved are dependent upon the effectuation in practice of specific measures, for instance with respect to adjustments in the situation and arrangement of collection points. It would be reasonable to assume that this observation is not merely applicable for this specific network. Combining this observation with some of the observations mentioned in Chapter 1 of this thesis with respect to the significant contribution of collection costs "to the overall end-of-life management costs" [Mulder,

1999] and the fact that actual collected quantities have "to be the basis of the dimensioning of redistribution systems" [Hansen, 2000] illustrates the possible repercussions of ignoring the collection stage within research dedicated to optimising Product Recovery Networks. Perhaps this thesis could contribute to the work of other researchers in this field by emphasising the importance of not treating the collection stage as a given.

A final topic that deserves attention at this point refers to the research approach that has been applied in this thesis. Obviously, a full adjudication of the effectiveness of the applied approach and included methods is hampered by the fact that the designed measures have not yet been effectuated in practice. Therefore, if and when these measures have been introduced in practice, it would be extremely beneficial to assess the effectiveness of those measures and evaluate the research method applied in this thesis based on the outcomes of that assessment.

However, based on all the foregoing, one preliminary conclusion can be drawn.

The design effort presented in this thesis combines a psychological conceptual model (Triad model) with a design method (Morphological Chart Method) within the framework of a structured design process (applying the methodologies by Jones [1981/1984] and Cross [1994]) in an effort to include all relevant aspects in the design alternatives that are generated. In this particular thesis, they have been applied to design (improved) policy measures to influence consumer behaviour with respect to the disposal of 'small' consumer electronics. However, the applicability of the Triad model certainly is not limited to that particular type of behaviour and could be applied to various other (non-)consumer behaviours as well. Similarly, the methodology and methods applied to structure and execute the design process in this thesis represent generic methodologies and methods that could also be applied to other types of policy measures (or completely different types of design objects for that matter). Therefore, there is no reason to assume that the specific research approach and included methods, as described in this thesis, could not be applied for design efforts that focus on other (types of) policy measures for other (types of) consumer behaviour. At first sight, combining the Triad model and the Morphological Chart Method offers the opportunity to establish all relevant determinants for a particular behaviour and to ensure the inclusion of all of these aspects in policy measures that are designed to influence this behaviour. The analysis presented in this thesis has not revealed any apparent barriers for generalisation. However, further research certainly is needed to fully assess all strengths and weaknesses of this approach.

Appendix I

Disposal of white and brown goods Decree

Decree of April 21, 1998

No. 238

to establish rules for taking back and processing white and brown goods after use (Disposal of White and Brown Goods Decree)

§ 1 General provisions

Section 1

In this decree and the provisions based thereon the following definitions shall apply:

a. product: a product that belongs to a category of white or brown goods designated in appendix 1 to this decree, which category has been elaborated in a ministerial decision;

b. manufacturer: any party who manufactures a product and is the first to make it available to another party in the Netherlands;

c. importer: any party who is the first to import a product into the Netherlands and to make it available to another party;

d. supplier: any party who provides a new product in the Netherlands to the party who is going to use that product;

e. repair company: a company that engages solely in repairing products;

f. cycle deficit: the negative balance that occurs when the cost of disposing of a product is higher than the revenue from that disposal.

Section 2

It is prohibited to incinerate products that have been collected or taken back separately in plants for the incineration of wastes as referred to in category 28.4 of appendix I or in category 2 of appendix III of the Establishments and Permits Decree (Environmental Management Act) (Inrichtingen- en vergunningenbesluit milieubeheer).

Section 3

1. It is prohibited to have in stock for commercial purposes refrigerators and freezers discarded after use and designated in category 1 in the appendix to this decree, which appliances contain substances or preparations as referred to in Section 2(1) or Section 12(1) of the 1995 decree governing substances that deplete the ozone layer.

2. The refrigerators and freezers referred to in subsection 1 shall be processed in an environmentally sound manner. Our Minister will lay down specific rules relating to the method of processing.

§ 2 Covenants

Section 4

Manufacturers or importers shall be exempted from the duties imposed on them in Sections 7 to 12 inclusive if they are signatories to a covenant between Our Minister and in any event one or several manufacturers or importers in which binding agreements have been made on the implementation of in any event the duties imposed in sections 7 to 12 inclusive.

§ 3 Individual duties

Section 5

When supplying a new product, suppliers shall take back as a minimum free of charge a similar product that has been discarded after use and that is tendered to them.

Section 6

1. Provincial environmental ordinances shall stipulate that within seven months of this decree becoming applicable to categories of products 1, 4, 5, 7, 8, 9 and 10 local authorities shall provide for:

a. separate collection of the products originating from private households and belonging to that category;

b. the creation and maintenance of a place within the municipality or within the municipalities with which they are working together where a supplier can leave a product taken back from a private household and belonging to that category.

2. Subsection 1 shall apply mutatis mutandis to categories of products 2, 3, 6, 11, 12, 13 and 14, subject to the proviso that within one year of this decree becoming applicable to these categories local authorities shall make provision for what is stipulated in subsection 1(a) and (b).

3. The local authority shall accept a product tendered by a supplier or a repair company at the place referred to in subsection 1(b), which product has been taken back from a private

household, to the extent the local authority can hand in the product in question to a manufacturer or importer as provided in Sections 7 or 8.

Section 7

1. Manufacturers and importers shall ensure that a product of the brand that they have put or are putting on the market in the Netherlands is taken back and further disposed of if it is tendered to them by a repair company or by the local authority.

2. Manufacturers and importers shall ensure that if, when providing a supplier with a new product, a similar product is tendered to them, this product is taken back and further disposed of.

Section 8

Products that have been discarded by private households and have been collected by the local authority shall be taken back from the place referred to in Section 6, subsection 1(b).

Section 9

Manufacturers or importers shall finance the cycle deficit from the supplier, the repair company and from the place referred to in Section 6, subsection 1(b).

Section 10

1. Within thirteen weeks of the duties referred to in Sections 7, 8 and 9 becoming applicable to them, manufacturers and importers shall give Our Minister notification of the manner in which they will perform the duties referred to in these Sections.

2. This notification shall as a minimum state:

a. the way in which products will be taken back from the supplier, the repair company or the local authority;

b. what percentage of the products taken back will be reused;

c. what percentage of the remaining products taken back, or components thereof, will be disposed of in a different manner;

d. how the disposal scheme will be financed;

e. the measures that will be taken to ensure that products are taken back and further disposed of if the manufacturer or importer ceases to market products in the Netherlands;

f. monitoring of the subjects referred to in a. to and including e. above.

3. If the products taken back contain batteries not governed by Sections 4 or 5 of the Battery Disposal Decree (Besluit Verwijdering Batterijen), the way in which these batteries will be disposed of shall also be stated.

4. Notification shall be valid for a period stated therein, being not more than five years.

Section 11

1. The notification referred to in Section 10 shall require the approval of Our Minister.

2. Subsections 3.5.2 to and including 3.5.5 of the General Administrative Law Act (Algemene Wet Bestuursrecht) shall apply to the preparation of a decree as referred to in subsection 1.

3. Our Minister may attach regulations or restrictions to his approval of the notification. He may also stipulate that the approval applies for a period shorter than the one referred to in Section 10, subsection 4.

4. If Our Minister has approved the notification for a specific period, the manufacturer or importer in question shall give notification as referred to in Section 10 within 6 months of this period expiring.

5. Until Our Minister has approved the notification, a manufacturer or importer shall, contrary to Sections 7, 8 and 9, ensure that after it has been taken back a product is stored.

Section 12

1. Manufacturers and importers shall perform the duties referred to in Sections 7, 8 and 9 in accordance with the notification as approved by Our Minister.

2. Each year, prior to 1 July, they shall send Our Minister a report on the manner in which the duties referred to in Sections 7, 8 and 9 were performed in the preceding calendar year.

Section 13

1. Manufacturers or importers may give joint notification as referred to in Section 10 and may submit a joint report as referred to in Section 12, subsection 2.

2. A manufacturer or importer shall be exempted from the duties imposed in Sections 10 and 12(2) if he is affiliated to an organisation of manufacturers or importers who perform these duties on his behalf.

§ 4 Concluding provisions

Section 14

With effect from 1 January 2005 Section 7, subsection 2 and the designation in subsection 1 shall lapse and "a repair company or the local authority" shall be replaced by "a supplier, a repair company or the local authority".

Section 15

This decree shall come into force on a date to be fixed by Royal Decree, which date may be fixed differently for the various Sections or parts thereof.

Section 16

This decree shall be referred to as the Disposal of White and Brown Goods Decree.

We order and command that this decree and the accompanying explanatory memorandum be published in the Bulletin of Acts, Orders and Decrees (Staatsblad).

The Minister of Housing, Spatial Planning and the Environment,

Appendix 1 to Section 1(a) of the Disposal of White and Brown Goods Decree

The categories of products as referred to in Section 1(a) are:

1. refrigerating and freezing equipment

2. heating equipment

3. hot-water equipment

4. washing and drying equipment

5. equipment for preparing food by heat

6. sound equipment

7. image receiving equipment

8. computers

9. paper printing equipment

10. telecommunications equipment

11. electric and electronic charging equipment

12. electric and electronic kitchen appliances

13. electric and electronic tools

14. other electric and electronic domestic appliances.

References

- Ajzen, I. (1985) “From intentions to actions: a theory of planned behavior”, in *Action-control: from cognition to behavior*, edited by Kuhl, J., and J. Beckmann (Heidelberg: Springer).
- Ajzen, I. (1991) “The theory of planned behavior”, *Organizational Behavior and Human Decision Processes*, Vol. 50: pp. 179-211.
- Ajzen, I., and J.T. Madden (1986) “Prediction of goal-oriented behavior: attitudes, intentions, and perceived control”, *Journal of Experimental Social Psychology*, Vol. 22: pp. 453-474.
- Ajzen, I., and M. Fishbein (1977) “Attitude-behavior relations: a theoretical analysis and review of empirical research”, *Psychological Bulletion*, Vol. 84: pp. 888-918.
- Ajzen, I., and M. Fishbein (1980) *Understanding attitudes and predicting social behavior* (Englewood Cliffs, New Yersey, USA: Prentice-Hall).
- Anderson, N.H., and J. Shanteau (1977) “Weak inferences with lineair models”, *Psychological Bulletin*, Vol. 84: pp. 1155-1170.
- Ansems, A.M.M., and R.N. van Gijlswijk (2002) *Controle/management zware metalen tijdens de verwerking van afgedankte elektronica production* (TNO-report R 2002/194; Apeldoorn, the Netherlands: TNO Milieu, Energie en Procesinnovatie).
- ARA Holding nv (2000) *Proefinzameling klein wit- en bruingoed via de detailhandel in de gemeente Arnhem* (final report in pilot project dedicated to collecting ‘small’ consumer electronics in Arnhem; Arnhem, the Netherlands: ARA Holding nv).
- Bagozzi, R. (1992) “The self-regulation of attitudes, intention, and behavior”, *Social Psychology Quarterly*, Vol. 55: pp. 178-204.
- Bagozzi, R., Yi, Y., and Baumgartner, J. (1990) “The level of effort required for behaviour as a moderator of the attitude-behaviour relation”, *European Journal of Social Psychology*, Vol. 20: pp. 25-59.
- Bandura, A. (1977) “Self-efficacy: toward a unifying theory of behavioral change”, *Psychological Review*, Vol. 84: pp. 191-215.
- Berger, C., Chauny, F., Langevin, A., Loulou, R., Riopel, C., Savard, G., and J.-P. Waaub (1998) “EUGENE: An Optimization-based Decision Support System for Long Term Integrated Regional Solid Waste Management Planning”, paper presented at *International Workshop on Systems engineering models for waste management* (Göteborg, Sweden: www.entek.chalmers.se/~josu/art-cber.htm).
- Bertens, C.A.W. et al. (1997) *Consumentenhouding en –gedrag m.b.t. de verwijdering van afgedankte elektrische huishoudelijke apparaten* (report on survey within the framework of Apparetour; Zoetermeer, the Netherlands: EIM).
- Boldero, J. (1995) “The prediction of household recycling of newspapers: The role of attitudes, intentions, and situational factors”, *Journal of Applied Social Psychology*, Vol. 25: pp. 440-462.
- Bratt, C. (1999) “The impact of norms and assumed consequences on recycling behavior”, *Environment and Behavior*, Vol. 31., No. 5: 630-656.
- Brombacher, A.C., and A.J. de Ron (1998) *Optimalisatie van de logistieke functies in een terugwinketen* (BETA Research proposal; Eindhoven, the Netherlands: A.C. Brombacher and A.J. de Ron, Section Quality of Products and Processes, Technology Management, Eindhoven University of Technology).

- Bureau Milieu & Werk (2000) *Proef inzameling kleine huishoudelijke apparaten* (final report on pilot project dedicated to collecting 'small' domestic electronics in Heemskerk; Tilburg, the Netherlands: Bureau Milieu & Werk).
- Carter, C.R., and L.M. Ellram (1998) "Reverse logistics: a review of the literature and framework for future investigation", *Journal of Business Logistics*, Vol. 19, No. 1: pp. 102.
- Caruso, C., Colorni, A., and M. Paruccini (1993) "The regional urban solid waste management system: A modelling approach", *European Journal of Operational Research*, Vol. 70, No. 1: pp. 16-30.
- Cheung, S.F., Chan, D.K.-S., and Z.S.-Y. Wong (1999) "Reexamining the theory of planned behavior in understanding wastepaper recycling", *Environment and Behavior*, Vol. 31, No. 5: pp. 587-612.
- Clegg, A.J., Williams, D.J., and R. Uzsoy (1995) "Production planning for companies with remanufacturing capability", *Proceedings of the IEEE Symposium on Electronics and the Environment* (Orlando, Florida, United States of America) pp. 186-191.
- Cohen, M.A., Nahmias, S., and W.P. Pierskalla (1980) "A dynamic inventory system with recycling", *Naval Research Logistics Quarterly*, Vol. 27, No. 2: 289-296.
- Commission of the European Communities (2000) *Proposal for a Directive of the European Parliament and of the Council on waste electrical and electronic equipment, Proposal for a Directive of the European Parliament and of the Council on the restriction of the use of certain hazardous substances in electrical and electronic equipment* (COM(2000) 347 final; Brussels, Belgium: the Commission).
- CREM (1999) *Resultaten nulmeting WEB 1998* (report commissioned by Ministerie van VROM; Amsterdam, the Netherlands: Consultancy and Research for Environmental Management).
- Cross, N. (1994) *Engineering Design Methods: Strategies for Product Design* (second edition; Chichester, UK: John Wiley & Sons Ltd.).
- De Kruijk, M.D., Pieters, F.G.M., Van Raaij, W.F., and H.W. Mentink (1993) *Milieugedragsmonitor: Secundaire analyse van de derde meting* (report; Rotterdam, the Netherlands: Vakgroep ESP, Erasmus Universiteit).
- De Straat Milieu-adviseurs B.V. (1999) *Proefproject inzameling klein wit- en bruingoed gemeente Delft: Uw oude apparaat voor een nieuwe fiets* (final report on pilot project dedicated to collecting 'small' consumer electronics in Delft; Delft, the Netherlands: De Straat Milieu-adviseurs B.V.).
- Deutscher, I. (1966) "Words and deeds: social science and social policy", *Social Problems*, Vol. 13: pp. 235-254.
- Dutch Government (2001) *Een wereld en een wil, werken aan duurzaamheid, Nationaal Milieubeleidsplan 4* (policy note; The Hague, the Netherlands: het kabinet).
- Feather, N.T. (1982) "Human values and the prediction of action: and expectancy-valence analysis", in *Expectations and Actions: Expectancy-Value Models in Psychology*, edited by N.T. Feather (Hillsdale, N.J.: Lawrence Erlbaum).
- Fischhoff, B., Goitein., B., and Z. Shapira (1982) "The experienced utility of the expected utility approaches", in *Expectations and Actions: Expectancy-Value Models in Psychology*, edited by N.T. Feather (Hillsdale, N.J.: Lawrence Erlbaum).
- Fishbein, M. (1963) "An investigation of the relationships between beliefs about an object and the attitude toward that object", *Human Relations*, Vol. 16: pp. 233-240.
- Fishbein, M. (ed., 1967) *Readings in Attitude Theory and Measurement* (New York, USA: Wiley).
- Fishbein, M., and I. Ajzen (1975) *Belief, attitude, intention, and behavior: An introduction to theory and research* (Reading, MA, USA: Addison-Wesley).

- Flapper, S.D.P. (1994) “Matching material requirements and availabilities in the context of recycling: An MRP-I based heuristic”, *Proceedings of the Eighth International Working Seminar on Production Economics* (Igls/Innsbruck, Austria) Vol.3: pp. 511-519.
- Fleischmann, M, H.R. Krikke, R. Dekker, and S.D.P. Flapper (2000) “A characterisation of logistics networks for product recovery”, *Omega: The International Journal of Management Science*, Vol. 28, No. 6: pp. 653-666.
- Fullerton, D., and T.C. Kinnaman (1995) “Garbage, recycling, illicit burning and dumping”, *Journal of Environmental Economics and Management*, Vol. 29: pp. 78-91.
- Fullerton, D., and T.C. Kinnaman (1996) “Household responses to pricing garbage by the bag”, *American Economic Review*, Vol. 86: pp. 971-984.
- Giuntini, R., and T. Andel (1995) “Advance with reverse logistics”, *Transportation & distribution: the logistics management magazine*, Vol. 36, No. 2: pp. 73-74,77.
- Guagnano, G.A., Stern, P.C., and T. Dietz (1995) “Influences on attitude-behavior relationships: a natural experiment with curbside recycling”, *Environment and Behavior*, Vol. 27: pp. 699-718.
- Guide Jr. V.D.R., Kraus, M.E., and R. Srivastava (1997<1>) “Scheduling policies for remanufacturing”, *International Journal of Production Economics*, Vol. 48, No. 2: pp. 187-204.
- Guide Jr., V.D.R. (1996) “Scheduling using drum-buffer-rope in a remanufacturing environment”, *International Journal of Production Research*, Vol. 34, No. 4: pp. 1081-1091.
- Guide Jr., V.D.R., Srivastava, R., and M.S. Spencer (1997<1>) “An evaluation of capacity planning techniques in a remanufacturing environment”, *International Journal of Production Research*, Vol. 35, No. 1: pp. 67-82.
- Guide, V.D.R., Jr., M.E. Kraus, and R. Srivastava (1997<2>) “Scheduling policies for remanufacturing”, *International Journal of Production Economics*, Vol. 48: pp. 187-204.
- Guiltinan, J.P., and N.G. Nwokoye (1975) “Developing distribution channels and systems in the emerging recycling industries”, *International Journal of Physical Distribution*, Vol. 6, No. 1: pp. 28-38.
- Gungor, A., and S.M. Gupta (1999) “Issues in environmentally conscious manufacturing and product recovery: a survey”, *Computers & Industrial Engineering*, Vol. 36, No. 4: pp. 811-853.
- Gupta, S.M., and K.N. Taleb (1994) “Scheduling disassembly”, *International Journal of Production Research*, Vol. 32, No. 8: pp. 1857-1866.
- Hansen, U. (2000) “Reverse Logistics is the Key for Remanufacturing and a Sustainable Development”, *Proceedings of the 2000 IEEE International Symposium*: pp. 238 –242.
- Hart, S.L. (1997) “Beyond Greening: Strategies for a Sustainable World”, *Harvard Business Review*, Vol. 75, No. 1: pp.66-76.
- Heidemij Advies B.V. (1997) *Onderzoek naar inzamelingsresultaten Apparetour* (report on collection rates/sorting analysis within the framework of Apparetour; Arnhem, the Netherlands: Heidemij Advies B.V.).
- Heyman, D.P. (1977) “Optimal disposal strategies for a single-item inventory system with returns”, *Naval Research Logistics Quarterly*, Vol. 24: pp. 385-405.
- Hoevenagel, R., Van Rijn, U., Steg, L., and H. De Wit (1996) *Milieurelevant consumentengedrag, Ontwikkeling conceptueel model* (Interimrapport, Rapportage eerste fase project milieurelevant consumentengedrag; Rijswijk, the Netherlands: Sociaal en Cultureel Planbureau (VUGA)).

- ICT Milieu (2002) *The ICT take back system: No visible fee necessary* (http://www.nederlandict.nl/ictinzamelgb.htm).
- Inderfurth, K. (1996) *Modeling period review control for a stochastic product recovery problem with remanufacturing and procurement leadtimes* (Working paper 2/96; Magdeburg, Germany: Faculty of Economics and Management, University of Magdeburg).
- Inderfurth, K. (1997) "Simple optimal replenishment and disposal policies for a product recovery system with leadtimes", *OR Spektrum*, Vol. 19: pp. 111-122.
- Informatiecentrum Preventie en Hergebruik (1998) *Verwijdering wit- en bruingoed: Handreiking voor gemeenten* (manual IPH 98-04; Utrecht, the Netherlands: Informatiecentrum Preventie en Hergebruik).
- Inman, R.A. (1999) "Environmental management: new challenges for production and inventory managers", *Production and Inventory Management Journal*, Vol. 40, No.3: pp. 46-49.
- ITM Research/CREM/VROM (1999) *Consumentenenquete WEB-monitoring* (report project Q107; Amsterdam, the Netherlands: ITM Research).
- Jahre, M. (1995<1>) "Household waste collection as a reverse channel: A theoretical perspective", *International Journal of Physical Distribution & Logistics*, Vol. 25, No. 2: pp. 39-55.
- Jahre, M. (1995<2>) *Logistics systems for recycling – efficient collection of household waste* (dissertation; Göteborg, Sweden: Chalmers University of Technology).
- Jahre, M. (1998) "The Logistics Costs of Collecting Recyclable Household Waste – Modelling Systems for Cost Consequence Analysis", paper presented at *International Workshop on Systems engineering models for waste management* (Göteborg, Sweden: www.entek.chalmers.se/~josu/art-mjah.htm).
- Jahre, M., and B. Flygansvaer (1996) "Comparing systems for collection, reuse and recycling in the case of electronics – theoretical framework and propositions", *Proceedings of the First International Working Seminar on Reuse* (Eindhoven, the Netherlands): pp. 189-204.
- Jenkins, R.R., Martinez, S.A., Palmer, K., and M.J. Podolsky (1999) *The Determinants of Household Recycling: A Material Specific Analysis of Unit Pricing and Recycling Program Attributes* (discussion paper; USA: Environmental Protection Agency).
- Johnson, M.R., and M.H. Wang (1995) "Planning product disassembly for material recovery opportunities", *International Journal of Production Research*, Vol. 33, No. 11: pp. 3119-3142.
- Jones, J.C. (1981) *Design Methods* (Chichester, UK: John Wiley & Sons Ltd.).
- Jones, J.C. (1984) "A Method of Systematic Design", in *Developments in Design Methodology*, edited by N. Cross (Chichester, UK: John Wiley & Sons Ltd.).
- Klompers, L.F.C.M., Ploos van Amstel, J.J.A., and Bakkers, F.T.P.G. (1997) *Nationaal proefproject inzameling en herverwerking wit- en bruingoed in de Regio Eindhoven, Apparetour: Deelrapport Inzameling en Logistiek* (report on one of three subprojects within Apparetour; Eindhoven, the Netherlands: Ploos van Amstel Milieu Consulting B.V.).
- Koster, , M.B.M. de, Flapper, S.D.P., Krikke, H.R., and W.S. Vermeulen (2002) "Logistic networks for the collection and processing of used big white goods", submitted to *Production & Operation Management (April 2002).*
- Krikke, H.R. (1998) *Recovery strategies and reverse logistic network design* (dissertation; Enschede, the Netherlands: University of Twente).
- Lemmens, A.M.C. (1998) *Projectvoorstel: Sluiten van de cyclus zware metalen in de consumentenelectronica door het optimaal afstemmen van product-ontwerp en de*

verwerking in de einde-leven-fase (Research project proposal IZW98301; Eindhoven, the Netherlands: Lex Lemmens, Technologie voor Duurzame Ontwikkeling, Eindhoven University of Technology).
- Liebrand, W.B.G., and P.A.M. Van Lange (1989) "Wat is een sociaal dilemma?", Chapter 1 of *Als het mij maar niets kost!, de psychologie van sociale dilemma's*, edited by Liebrand, W.M.G., and P.A.M. Van Lange (Amsterdam, the Netherlands: Swets & Zeitlinger B.V.).
- Linderhof, V., Kooreman, P., Allers, M., and D. Wiersma (2001) "Weight-based pricing in the collection of household waste: the Oostzaan case", *Resource and Energy Economics*, Vol. 23: pp. 359-371.
- Lindsay, J.J., and A. Stratham (1997) "Predictors of Recycling Behavior: An Application of a Modified Health Belief Model", *Journal of Applied Social Psychology*, Vol. 27, No. 20: pp. 1799-1823.
- Lüdemann, C. (1999) "Subjective expected utility, thresholds, and recycling", *Environment and Behavior*, Vol. 31, No. 5: pp. 613-629.
- Lund, R.T. (1984) "Remanufacturing", *Technology Review*, Vol. 87, No. 2: pp. 19-29.
- Mabini, M.C., Pintelon, L.M., and L.F. Gelders (1992) "Repairable item inventory systems: A literature review", *Belgian Journal of Operations Research, Statistics and Computer Science*, Vol. 30, No. 4: pp. 57-69.
- Mallen, B. (1970, reprinted in 1996) "Selecting channels of distribution: a multi-stage process", *International Journal of Physical Distribution & Logistics Management*, Vol. 26, No. 5: pp. 5-21.
- Maloney, M.P., and M.P. Ward (1973) "Ecology: Let's hear from the People", *American Psychologist*, Vol. 28: pp. 583-586.
- McGuire, W.J. (1986) "The vicissitudes of attitudes and similar representational constructs in twentieth century psychology", *European Journal of Social Psychology*, Vol. 16: pp. 89-130.
- Melissen, F.W., and A.J. de Ron (1999) "Defining Recovery Practices: Definitions and Terminology", *International Journal of Environmentally Conscious Design & Manufacturing*, Vol. 8, No. 2: pp. 1-18.
- Melissen, F.W., and A.J. de Ron (2001) "Industrial Dynamics Modelling as a Product Recovery Network design tool", in *Proceedings of the 8th International Seminar on Life Cycle Engineering* (Varna, Bulgaria: A.J. de Ron and Technical Mechanical Union of Bulgaria): pp. 47-56.
- Mirchandani, P.B., and R.L. Francis (1989) *Discrete Location Theory* (New York, U.S.A.: Wiley).
- Mitchell, T.R. (1982) "Expectancy-value models in organizational psychology", in *Expectations and Actions: Expectancy-Value Models in Psychology*, edited by N.T. Feather (Hillsdale, N.J.: Lawrence Erlbaum).
- Muckstadt, J.A., and M.H. Isaac (1981) "An analysis of single item inventory systems with returns", *Naval Research Logistics Quarterly*, Vol. 28: pp. 237-254.
- Mulder, L. (1999) "Collecting electronic waste in Europe: A Sony view", *Proceedings of the 1999 IEEE International Symposium*: pp. 244 –250.
- Nordic Council of Ministers (1995) *Waste from electrical and electronic products – a survey of the contents of materials and hazardous substances in electric and electronic products* (report TemaNord 1995; Copenhagen, Denmark: Nordic Council of Ministers).
- NVMP (2002) *Landelijke inzamelresultaten 2001 elektrische apparaten* (http://www.nvmp.nl/html/01_nvmp/00_d_home.htm).

- NVMP (2002) *Regulation for disposal of electrical goods in the Netherlands* (http://www.nvmp.nl/html/10_english/01_d_english.htm).
- Oskamp, S. (1995) "Resource Conservation and Recycling: Behavior and Policy", *Journal of Social Issues*, Vol. 51, No. 4: pp. 157-177.
- Oskamp, S., Burkhardt, R.L., Schultz, P.W., Hurin, S., and L. Zelezny (1998) "Predicting Three Dimensions of Residential Curbside Recycling: An Observational Study", *The Journal of Environmental Education*, vOL. 29, No. 2: pp. 37-42.
- Oskamp, S., Harrington, M.J., Edwards, T.C., Sherwood, D.L., Okuda, S.M., and D.C. Swanson (1991) "Factors influencing household recycling behavior", *Environment and Behavior*, Vol. 23: pp. 494-519.
- Penev, K.D. (1996) *Design of disassembly systems: a systematic approach* (dissertation; Eindhoven, the Netherlands: Eindhoven University of Technology).
- Petty, R.E., and J.T. Cacioppo (1981) *Attitudes and Persuasion: Classic and Contemporary Approaches* (Dubuque, Iowa: Wm. C. Brown).
- Pieters, R.G.M. (1989) *Attitudes and Behavior in a Source-Separation Program: A Garbology Approach* (dissertation; Leiden, the Netherlands: Rijksuniversiteit Leiden (eburon delft)).
- Pieters, R.G.M. (1991) "Changing Garbage Disposal Patterns of Consumers: Motivation, Ability, and Performance", *Journal of Public Policy & Marketing*, Vol. 10, No. 2: pp. 59-76.
- Pohlen, T. L., and M.T. Farris II (1992) "Reverse Logistics in Plastics Recycling", *International Journal of Physical Distribution & Logistics Management*, Vol. 22, No. 7: pp. 35-47.
- Poiesz, T.B.C. (1995) *Understanding and changing human behavior; an introduction to the Triad Model* (Draft version; Tilburg, the Netherlands: manuscript by Theo B.C. Poiesz).
- Poiesz, T.B.C. (1999) *Gedragsmanagement: Waarom mensen zich (niet) gedragen* (Wormer, the Netherlands: Inmerc bv).
- Porter, B.E., Leeming, F.C., and W.O. Dwyer (1995) "Solid Waste Recovery, A Review of Behavioral Programs to Increase Recycling", *Environment and Behavior*, Vol. 27, No. 2: pp. 122-152.
- PriceWaterhouseCoopers (1999) *Collectief systeem voordelig voor individuele producenten/importeurs en milieu* (report commissioned by the NVMP; Utrecht, the Netherlands: PriceWaterhouseCoopers).
- PriceWaterhouseCoopers (2001) *Collectief systeem voordelig voor individuele producenten/importeurs en milieu* (report commissioned by the NVMP; Utrecht, the Netherlands: PriceWaterhouseCoopers).
- PriceWaterhouseCoopers (2001) *NVMP-systeem is doelmatig, het fonds is echter aan de hoge kant* (report commissioned by the NVMP; Utrecht, the Netherlands: PriceWaterhouseCoopers).
- Projectburo Hergebruik NO-Nederland, Prozon Milieutechniek BV, and Wolter Potze Milieu BV (1999) *Klein wit- en bruingoed, inzameling via de WEBbak* (final report on pilot project dedicated to the application of the so-called WeBbak; the Netherlands).
- Richter, K. (1996) "The EOQ repair and waste disposal model with variable setup numbers", *European Journal of Operational Research*, Vol. 95: pp. 313-324.
- RIVM/CBS (2001) *Dutch Environmental Data Compendium 2001* (http://www.rivm.nl/environmentaldata/).

- Sarkis, J. (2001) “Manufacturing’s role in corporate environmental sustainability: Concerns for the new millennium”, *International Journal of Operations & Production Management*, Vol. 21, No. 5/6: pp. 666-686.
- Schoemaker, P.J.H. (1982) “The expected utility model: Its variants, purposes, evidence and limitations”, *Journal of Economic Literature*, Vol. 20: pp. 529-563.
- Schrady, D.A. (1967) “A deterministic inventory model for repairable items”, *Naval Research Logistics Quarterly*, Vol. 14: pp. 391-398.
- Schultz, P.W., and S. Oskamp (1996) “Effort as a moderator of the attitude-behavior relationship: General environmental concern and recycling”, *Social Psychology Quarterly*, Vol. 59, No. 4: pp. 375-383.
- Schultz, P.W., Oskamp, S., and T. Mainieri (1995) “Who recycles and when?: A review of personal and situational factors”, *Journal of Environmental Psychology*, Vol. 15: pp. 105-121.
- Schwartz, S.H. (1975) “The justice of need and the activation of humanitarian norm”, *Journal of Social Issues*, Vol. 31: pp. 111-136.
- Schwartz, S.H. (1977) “Normative influence on altruism”, in *Advances in Experimental Social Psychology*, edited by L. Berkowitz (New York, USA: McGraw Hill).
- Spengler, ., Pückert, H., Penkuhn, T, and O. Rentz (1997) “Environmental integrated production and recycling management”, *European Journal of Operational Research*, Vol. 97, No.2: pp. 308-326.
- Staatsblad 238 (1998) “Besluit van 21 april 1998, houdende vaststelling van regels voor het na gebruik innemen en verwerken van wit- en bruingoed (Besluit verwijdering wit- en bruingoed)”, *Staatsblad van het Koninkrijk der Nederlanden*, no. 238: pp. 1-28.
- Steenwinkel, I.S. et al. (1997) *Bevolkingsonderzoek Apparetour* (report on survey within the framework of Apparetour; Rotterdam, the Netherlands: CEA).
- Stichting NVMP (2002) *Monitoringsverslag over 2001* (report; http:/www.nvmp.nl: NVMP).
- Taylor, S., and P. Dodd (1995) “An integrated model of waste management behavior: A test of household recycling and composting intentions”, *Environment and Behavior*, Vol. 27: pp. 603-630.
- Thierry, M.C. (1997) *An analysis of the Impact of Product Recovery Management on Manufacturing Companies* (dissertation; Rotterdam, the Netherlands: Erasmus University Rotterdam).
- Thierry, M.C., M. Salomon, J. van Nunen, and L. van Wassenhove (1995) “Strategic issues in product recovery management”, *California Management Review*, Vol. 37, No. 2: pp.114-135.
- Thogerson, J. (1996) “Recycling and morality: A critical review of the literature”, *Environment and Behavior*, Vol. 28: 536-558.
- Tucker, P. (1999) “Normative Influences in Household Waste Recycling”, *Journal of Environmental Planning and Management*, Vol. 42, No. 1: pp. 63-82.
- Tucker, P., and D. Smith (1999) “Simulating Household Waste Management Behaviour”, *Journal of Artificial Societies and Social Simulation*, Vol. 2, No. 3: http://www.soc.surrey.ac.uk/JASS/2/3/3.html.
- Tucker, P., G. Murney, and J. Lamont (1998) “A Decision Support Model for the Management of Recycling Schemes”, *Journal of Environmental Planning and Management*, Vol. 41, No. 4: pp. 445-462.
- Tucker, P., Speirs, D., and D. Smith (2000) “The Impact of a Change in Collection Frequency on Kerbside Recycling Behaviours”, *Journal of Environmental Planning and Management*, Vol. 43, No. 3: pp. 335-350.

- Van der Laan, E., Dekker, R., and M. Salomon (1996<1>) “An (s,Q) inventory model with remanufacturing and disposal”, *International Journal of Production Economics*, Vol. 46-47: pp. 339-350.
- Van der Laan, E., Dekker, R., and M. Salomon (1996<2>) “Product remanufacturing and disposal: A numerical comparison of alternative control strategies”, *International Journal of Production Economics*, Vol. 45: pp. 489-498.
- Van Eijk, P. (2002) *Water in de stedelijke vernieuwing: een participatieve strategie* (dissertation; Boxtel, the Netherlands: Aeneas).
- Van Meegeren, P. (1997) *Communicatie en maatschappelijke acceptatie van milieubeleid* (dissertation; Wageningen, the Netherlands: Landbouwuniversiteit Wageningen).
- Van Pol, L. (1996) *Apparetour, impact en imago* (report on survey within the framework of Apparetour; Eindhoven, the Netherlands: Ploos van Amstel Milieu Consulting B.V.).
- Van Raaij, W.F. (1974) *Consumer Choice Behavior: An Information Processing Approach* (dissertation; Tilburg, the Netherlands: Katholieke Hogeschool Tilburg).
- Veerman, K. (2002) *Drie jaar ervaring met het afvalbeheer van wit- en bruingoed* (report; Den Haag, the Netherlands: Kees Veerman, VROM).
- Vergeer, F.J. (2001) *Autonomie en welbevinden: een onderzoek naar de relatie tussen autonoom handelen van leerlingen en hun welbevinden op school* (dissertation; Nijmegen, the Netherlands: UB Nijmegen).
- Verschuren, P., and H. Doorewaard (1999) *Designing a Research Project* (Utrecht, the Netherlands: LEMMA).
- Verschuren, P.J.M. (1994) *De probleemstelling voor een onderzoek* (Utrecht, the Netherlands: Spectrum).
- Vinning, J., and A. Ebreo (1990) “What makes a recycler?: A comparison of recyclers and nonrecyclers”, *Environment and Behavior*, Vol. 22: pp. 55-73.
- Vinning, J., and A. Ebreo (1992) “Predicting recycling from global and specific environmental attitudes and changes in recycling opportunities”, *Journal of Applied Social Psychology*, Vol. 22: pp. 1580-1607.
- Visser, T.J. et al. (1997) *Waar een wil is..., inzamelen en recyclen van oude elektrische apparaten* (report on collection campaign in Geldrop; Amsterdam, the Netherlands: Milieudefensie).
- VROM (2002) *VROM - Taken en doelstellingen* (http:/www.vrom.nl/ pagina.html?id= 2684).
- Walley, N., and B. Whitehead (1994) “It’s not easy being green”, *Harvard Business Review*, Vol. 72, No. 2: pp. 46-52.
- Warshaw, P.R. (1980) “A new model for predicting behavioral intentions: an alternative to Fishbein”, *Journal of Marketing Research*, Vol. 17: pp. 153-172.
- Weiner, B. (1992) *Human Motivation, Metaphors, theories, and research* (New York, USA: Sage Publications).
- Wicker, A.W. (1969) “Attitudes versus actions”, *Journal of Social Issues*, Vol. 25: pp. 41-78.
- Wit, A.P. (1994) “De aanpak van het milieuvraagstuk vanuit sociaal dilemma perspectief”, Chapter 7 of *Consument en Milieu, Beoordeling van milieurisico’s en sturing van gedrag*, edited by Midden, C.J.H., and G.C. Bartels (Houten, the Netherlands: Bohn Stafleu Van Loghum).
- Witt, C.E. (1997) “Recycling: Collecting Is the First Step”, *Material Handling* Engineering, Vol. 53. No. 6: pp. 60-67.

- Wolff, R. (1998) “Beyond environmental management – Perspectives on environmental and management research”, *Business Strategy and the Environment*, Vol. 7, No. 5: pp. 297-308.
- Yangsoo, Y (1999) *Social structural and social psychological factors affecting household-level environmental decision-making: a three-country comparison of the determinants of household recycling behaviour* (dissertation; Louisville, Kentucky, USA: UMI Dissertation Services).