Cost effectiveness of sustainable housing investments

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Cost effectiveness of sustainable housing investments

Proefschrift

ter verkrijging van de graad van doctor
aan de Technische Universiteit Delft,
op gezag van de Rector Magnificus prof. dr. ir. J.T. Fokkema,
voorzitter van het College voor Promoties,
in het openbaar te verdedigen op maandag 28 februari 2005 om 13.00 uur

door

Tiemen DE JONGE

bouwkundig ingenieur,
geboren te Nijverdal.

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Contents

To my children
who inspired me with their enthusiasm to work on this thesis.
But above all to my dear wife Hanny.
Without her unconditional and persistent support, I never would have achieved this.

Prof. ing. A.F. Thomsen acted as my promotor. André did a great job, reviewing my work all the time and guiding me through the formalities.
From the start of my doctoral study in 2001 until October 2004, also Prof. ir. F. Seijffert acted as my promotor. Frits inspired and supported me, especially as to the subjects of the value of houses and the construction economics.
According to the PhD Doctorate Regulations, Frits was not allowed to act as a promotor after October 2004 because of his age.

Summary

Introduction

This study concerns the sustainability of the construction and use of buildings in the Dutch housing sector, as an example of the West European situation. Since the vast majority of sustainability problems concerning housing can be located in the existing stock, the study is aimed at the development of a decision-support tool for interventions in this stock, i.e. for renovation and redevelopment projects. This tool should provide information on the environmental burden of the projects, related to the design characteristics on the scale levels, which are usually referred to in different project stages, starting with the phase of project definition and following the design process up to the specification phase.

The research is linked to the model of the Eco-costs/Value Ratio (Vogtländer, 2001). It concerns the applicability of the model as a tool in design and decision-making processes preceding interventions in the housing stock. Therefore, the problem definition of the research reads:

Is estimating eco-costs and weighing them against intended value, on project level, a useful way of evaluating ex ante the ecological impact of (alternative) plans for interventions in the housing stock, in particular in the early stages of development processes?

In order to find an answer to this research question, the study has been started with the investigation of the concepts of the 'Eco-costs of housing' and the 'Value of houses'. Next, the study investigates what requirements are set by 'Design and development processes' for a decision-support tool referring to eco-costs. Based on the research conclusions, a prototype has been produced for an estimating model referring to both eco-costs and traditional costs of (re-) constructing and operating residential buildings in the context of interventions in the housing stock. Finally, some case studies are executed to evaluate what can be expected of applying a tool based on 'The Eco-costs/Value Ratio of housing'.

Eco-costs of housing

LCA-based approaches

The study starts with an investigation of models that can quantify the ecological burden of building projects. The most systematic method in this field is the Life Cycle Assessment (LCA). LCA provides a systematic approach to measuring resource consumption and emissions associated with products, processes and services. However, the traditional LCA is often considered to be too complicated and specialised to serve as a decision-support tool in development projects. Only environmental experts are able to interpret them, and even their complex decisions are not easy to communicate to the stakeholders in the projects. Therefore, in literature several models can be found that express the ecological burden of buildings in a single indicator. All of these models have slightly different goals and scopes. Three LCA-based models have been studied more closely: Eco-Quantum, Green-Calc and the model of the Eco-costs/Value Ratio (EVR).

The Eco-costs/Value Ratio

Unlike the concepts of Eco-Quantum and Green-Calc, the concept of EVR is independent from the type of product of which the ecological burden is assessed. The EVR is an LCA-based assessment model that expresses the ecological burden of a product or service in 'eco-costs'. The ratio compares these 'eco-costs' to the value of the product or service. A low EVR indicates that the product is fit for use in a future sustainable society. A high EVR indicates that the value/costs ratio of a product might become 'less than one' in the future, if the 'external' costs of the ecological burden will become part of the 'internal' cost-structure. This means that there is no market for such a product in the future (Vogtländer, 2001).

In principle, EVR supports assessments of all kinds of buildings, as long as the values of the buildings are comparable. Moreover, on that very basis, it allows comparing new construction to renovation or maintenance. As in particular this last characteristic is required for a decision-support tool concerning interventions in the existing housing stock, further research is focused on the possibilities of EVR.

One of the central concepts of the EVR model is defining eco-costs as the costs of technical measures to prevent pollution and resource depletion to a level, which is sufficient to make society sustainable. More specifically, the model is based on the virtual eco-costs '99 being the sum of the marginal prevention costs of the depletion of materials, energy consumption, toxic emissions, labour and depreciation related to the production and use of products and services. Like all models based on LCA do, the EVR model includes the whole life cycle of a product. In case of houses or other buildings, at least three phases of the product should be discerned to look at in particular: the production phase, the operating phase and the end-of-life phase.

Production phase

An important characteristic of building projects is that every project consists of a combination of semi-finished products, which are assembled at the building site. Therefore, the environmental burden (the eco-costs) of a building in the production phase can be considered as consisting of the eco-costs of those semi-finished products plus the eco-costs of the assembling activities (including all additional works like preparation works, building site facilities and management). So, in principle it is possible to estimate the eco-costs of a building applying 'eco-cost unit prices' of building elements. As is done in a traditional cost estimate based on unit prices, the composition of the concerned elements is determined in terms of quantities of characteristic semi-finished products and assembling activities. For these products and activities, the emission and depletion data, which serve as a basis for eco-costs assessments, can be found in data bases like IDEMAT, Eco-Invent and MARKAL. Hence, the eco-costs per unit of element can be determined by inserting the eco-costs of the semi-finished products and the assembling activities into the recipes of the elements. Finally, the elemental bills of quantities (for estimating traditional economic costs) can be transformed into eco-costs estimates by substituting eco-cost unit prices for the traditional economic unit prices.

In this way, eco-costs have been implemented in the materials database of an estimating system that is used to produce elemental bills of quantities for the construction costs of new construction and renovation projects. This way a tool has been acquired for estimating eco-costs in the production phase of these kinds of projects.

Operating phase

In the operating phase, the most important factors of ecological burden are the energy demand and the maintenance of the building in use. To support decisions in the design stage, related to the energy demand, an existing model has been used (DGMR, 2004). Architects can estimate the energy demand of residential buildings (in the Netherlands) with this model. It requires limited input, related to the main formal characteristics of the buildings, which enhances its applicability for decision-making in design. The energy demand estimating facility of this model can easily be integrated in the EVR approach. In recent years, several management models for maintenance have been developed in the Netherlands. However, these models seem to be too complicated for use in (early) design stages. In these stages, elaborated calculations of maintenance efforts are very unusual. At Delft University of Technology, an estimating model was elaborated for investigating the impacts of design decisions on the maintenance costs of residential buildings. Because of its basic structure and its connection to the NEN 2634, this model can be suitable for application by (Dutch) architects in early design stages. It can be integrated in the EVR assessment approach.

In the housing sector, management and administration costs are usually rather independent from the specific building design. For estimating the related eco-costs, these costs can be considered as mainly related to 'labour in offices'.

End-of-life phase

The costs of demolition and the separation of waste are covered by traditional economic costing. The pollution prevention costs of these activities can be estimated without considerable problems. The eco-costs of recycling or upgrading are assigned to the new products emerging from these processes. So, all eco-costs in the end-of-life phase after the separation of waste are related to the waste fraction that is not fit for upgrading or recycling. This fraction is charged with 'eco-costs of land fill'.

So far, a conceptual model has been developed for estimating the eco-costs in the entire lifecycle of housing. The study continues with the problem of balancing the eco-costs to the value of a dwelling and with the problem of mutually weighing the eco-costs in the various stages of its lifecycle.

The value of houses

Several approaches of value

Whereas in the housing sector many different methods are applied for assessing value, the question arises which determination of value is meaningful in this context.

In the (original) EVR model, the value – the amount for which a product or service can be exchanged in an open market – is identified by the 'sales price' within the business chain and the 'fair price' in the consumer market. For commodity goods, of which many items are sold and bought on a day-to-day basis, the value of products can be determined by observing sales prices. In real estate and housing markets, however, it is much less easy to establish the value of products by observing sales prices.

Exploring the value of houses starts with a theoretical exposition that can be summarised in the following statements, which are valid simultaneously:

- Value of houses is determined by (discounted cash flow of) future profits.
- Value of houses is related to the (actual) all-in building costs of houses.
- Value of houses is related to desirable characteristics/performance.
- Value of houses is gradually diminishing due to innovations.
- Value of houses is fluctuating by a combination of maintenance and loss of performance.
- Value of houses is related to their location in the context of trade-offs based on status and the social acceptability of dwelling quality.
- Value of houses is influenced by housing market factors (e.g. general shortage of housing) and other economic factors (e.g. interest levels).

Value and quality

As decisions in design processes mainly refer to the physical building characteristics of houses, research has been directed towards determining a relation between these characteristics and the value of houses.

In that context, Garvin's ideas concerning quality dimensions are – tentatively – elaborated for the Dutch housing sector (Garvin, 1988). Essential for these quality dimensions is that they are determined by product characteristics 'as perceived by the customers'. In the idea of Garvin, quality can be judged by the customers only. As to housing services, the value for the tenants, being the customers, can be expressed by the fair price rent. In the customer value model (Gale, 1994) such a fair price rent is related to the customers' appraisal of the various quality dimensions of the affected dwellings.

Value and time

The elaboration of the customer value model (Gale, 1994) has been connected to observations referring to the periodicity of adaptations in existing dwellings (Brand, 1994), to the development of the amount of living area used per person and to the replacement capacity of the construction industry in Europe (Thomsen, 2002). On this basis, a model has been produced concerning the development of the value of aging houses as related to the development of their discerned quality dimensions. The estimated value development of housing services based on this model is concluded to be consistent with other findings referring the aging of houses in the Dutch rental sector (Conijn, 1995).

Location aspects

The appreciation of the quality dimensions tends to be reduced in the course of time. After a period of 30 years following the initial construction of a dwelling the total quality rate, and by consequence the customer value, will be approximately 65% of the quality rate, respectively the customer value, of the new dwelling. Modification in the housing status of a particular location (Phe and Wakely, 2000) may interfere with this value development. However, since most houses in the same neighbourhood usually have more or less the same level of physical quality, this interference will hardly affect the relative value (i.e. market position) of the aging houses within that particular neighbourhood.

The value of houses that need reinvestment

The value of a dwelling as a real estate object for the landlord equals the (discounted cash flow of the) net future profits of that object. It is recommended that the net future profits are estimated, considering the above mentioned reduction of the quality rate for the housing services, which are provided by the dwelling. It should be kept in mind that after a term of 30 years, the quality of the dwelling will be perceived (by the customers) as being insufficient, and a reinvestment is probably required for further operation. The (residual) value of the dwellings at that moment should be estimated based on the expected reduction of the various quality dimensions of the provided housing services (using the model of Gale) and the possibilities of recovering quality, and value, by applying refurbishment, extensive renovation or new construction. So, the residual value at the end of the operating term is produced by the difference of the value of the dwelling after an intervention at that moment and the (all-in) costs of the very intervention.

$V_e = V_n - C$

In which V_e = (residual) value of the existing dwelling
V_n = value of the new dwelling created by the intervention
C = all-in construction costs of the intervention

Design and development processes

Flexible design process in a formal development process

While the design process allows an architect quite well to go up and down the composition hierarchy of a building (or complex) in order to evaluate several design alternatives on different levels, the sequence of formal development process stages is much more static. When in practice a certain phase is completed by an official client's approval, only very severe arguments can make the process return to that phase, otherwise, economic interests of the involved parties would be damaged too much. This static character of the development process sequence, as compared to the sequences in the design process, urges architects and other professionals in building development projects to be quick and lean in going 'up and down the design ladder' to evaluate possibilities of interesting design alternatives on different scale levels. Especially in the early stages, architects may want to evaluate several alternatives (for features on lower scale levels) on a very quick basis, because budget for extended research is usually not available.

Estimating tools should be able to follow this quickly going 'up and down'. In other words they need to offer 'ready and easy' cost information that can be used to evaluate design alternatives on different scale levels simultaneously, connecting the information on the discerned levels in a way that excludes double counting or omission.

Requirements for an estimating model

As remarked earlier, the environmental burden and, by consequence, eco-costs relate to all phases of the life-cycle of houses. So, eco-cost estimating should have the scope of a Life Cycle Costing approach. In order to fit in with the profession involved in housing projects, the applied technique in this respect should be the so-called operating estimate, in which e.g. maintenance and energy costs can be tuned to varying design specifications.

Many architects prefer to relate, as to building cost data, to their own expe-

riences from previous design commissions concerning similar buildings. They do so mainly, because in the early process stages no better alternative is usually available.
Using these self-made cost data for the early process stages has several drawbacks:

- They are unable to communicate relevant eco-cost information, since the raw data on this subject are not readily available.
- The (greater part of) project documents in architectural firms are not structured in such a way that the contained cost data can be modelled according to the (main) dimensions of preliminary design.
- In general, the cost information from these reference projects is poorly connected to the information in later development stages.

In addition, a need for more specified cost data will become evident very soon in the process. Design is then probably dealing with alternative building forms and several combinations of functional and/or spatial entities may be considered. Technical specification of building elements, however, may be still far away. In this stage of preliminary design, information is needed that relates costs to alternative combinations of (functional) project sections and varying dimensions of buildings.

Not until the process stages of definite design and specifications, cost information referring to more specified elements (i.e. technical solutions) is required or applicable, since the detailing of the design has not yet proceeded thus far. Only in these final stages, cost effects of applying different materials and semi-finished products are considered on a more extensive scale.

So, cost analysis should be closely related to the requirements from the design process. That means being specified if required, but global when the decisions involved have a global character; and, moreover, the model should be able to follow the designer ‘up and down the design ladder’, as mentioned before.

Filling in the missing link

At this point the existing tools for cost estimating apparently have a missing link. At the top end of the composition hierarchy, a general idea of building costs may be available, based on square metre prices of previously designed projects. At the bottom end, unit-prices of technical solutions may be available from a data base of cost analyses, which links specified elements (i.e. technical solutions) to the costs of materials, labour etc. through element recipes.

In between, however, the existing estimating tools do not provide information about which combination of technical solutions is characteristic for the actual type of building in the concerned development project.

To fill in this missing link, the Reference Projects Model has been composed. It provides the needed data, based on the idea that (within a building market region, e.g. the Netherlands) a building is a unique product, not so much because of the unique technical solutions it consists of, but much more because of the unique combination of (per se) similar technical solutions.

The Reference Projects Model

The idea behind the Reference Projects Model is that an architect deduces the construction costs of a new design from the construction costs of a project he already knows: the reference project. Evidently, projects that contain the architect's own designed buildings are the reference projects most suitable to him. So, in general, an architect should relate the new project, in which he actually is involved as a designer, to other projects from his own portfolio.
Two exceptions can be discerned on this rule:

- The architect is confronted with a commission referring to a category of buildings he is not acquainted with.
- There is not a database with well-structured cost data referring to the architect's portfolio.

In these situations a public database of reference projects could provide 'second best' cost data for early development process stages. The Reference Projects Model has been designed as such a database (Winket, 2004).

By using the model, architects (and clients) are able to estimate the costs of housing projects on an appropriate scale level in all stages of the development process. From the point of view of the estimating technique, there is only one difference between traditional construction costs and eco-costs in the model: eco-costs cannot be verified on the basis of realised tender prices.

Estimating tools for the Eco-costs/Value Ratio in housing projects

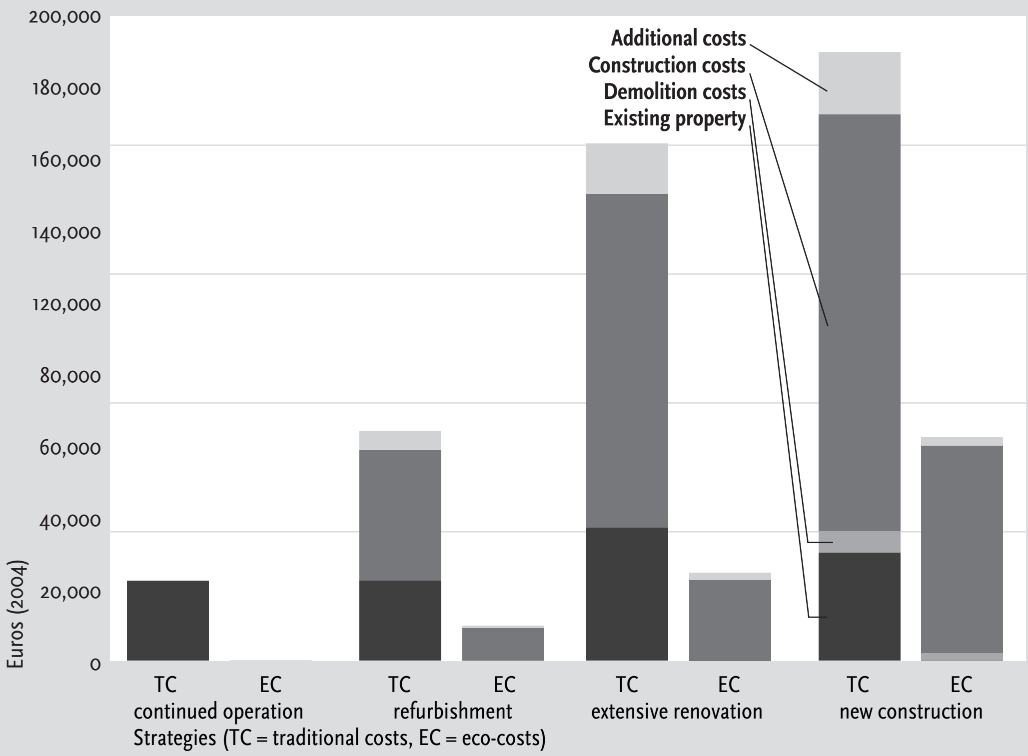
At this stage of the research, for calculations referring to the production phase and the end-of-life phase, the Reference Projects Model is operational. For calculations referring to the operating phase the spreadsheet facility for Estimating Energy Demand (DGMR, 2004) and the Delft Maintenance Calculating Model can be combined and connected to the input interface of the Reference Projects Model. Some engineering is still needed to make this combination of tools for the operating phase available for architects in real life projects.

The eco-costs/value ratio of housing

Eco-costs/Value Ratio on investment level

In order to illustrate the type of results that can be obtained by means of the developed models, two case studies have been conducted. First, the results of

Figure A Traditional costs and eco-costs of investments at several strategies



eco-cost calculations in fourteen recently completed building projects are presented. The emphasis in these projects is on housing, i.e. new construction as well as renovation. However, some non-residential projects are added in order to get a (preliminary) indication of the position of the housing sector as related to other building categories.

The results of these calculations show that new construction of houses and offices have Eco-costs/Value Ratios on similar levels. Renovation, however, shows significantly lower Eco-costs/Value Ratios than new construction.

Analysis of the calculation results indicates that this difference between new construction and renovation is mainly related to the combination of the relatively high ecological burden of Substructure, Structure and Skin elements of buildings in the production phase, and the fact that these elements have different approaches in new construction and renovation projects.

Analysis of the calculation results also indicates that the greater part of the eco-costs of buildings in the production phase can be traced back to a relatively small group of materials.

Applying the EVR model at housing stock intervention projects

Based on practical experience in several redevelopment and renovation projects, a case has been constructed in order to test the applicability of the developed model: In a complex of approximately 200 apartments, built in the 1960s, the landlord, a Dutch housing association, is planning to start an intervention project. The characteristic approach of such a project would be to conduct a feasibility study concerning various options in order to support a final project definition.

Apart from selling the apartments, in principle, four strategies – i.e. four types of interventions – are possible: unchanged continued operation, refurbishment aimed at improving one or more quality dimensions of the apartments as they are, extensive renovation aimed at creating (virtually) new apartments within the structure of the existing block and, finally, redevelopment aimed at the construction of completely new houses. For all of these strategies investment costs (traditional and eco-costs) have been estimated. The results of these investment calculations are presented in Figure A as traditional costs and eco-costs per apartment.

On investment level, the EVR of new construction clearly is the highest. Moreover, also in real figures, the all-in construction costs and eco-costs per apartment are the highest in new construction.

Eco-costs/Value Ratio of housing expenses

The allocation of eco-costs takes place in line with economic principles (everything based on the Present Value). This includes that the eco-costs of the indirect yield value (i.e. the present value of the operation) equal the eco-costs of the investment. Hence, the eco-costs of renting houses can be deduced from the eco-costs of the investment and the eco-costs of the operating expenses.

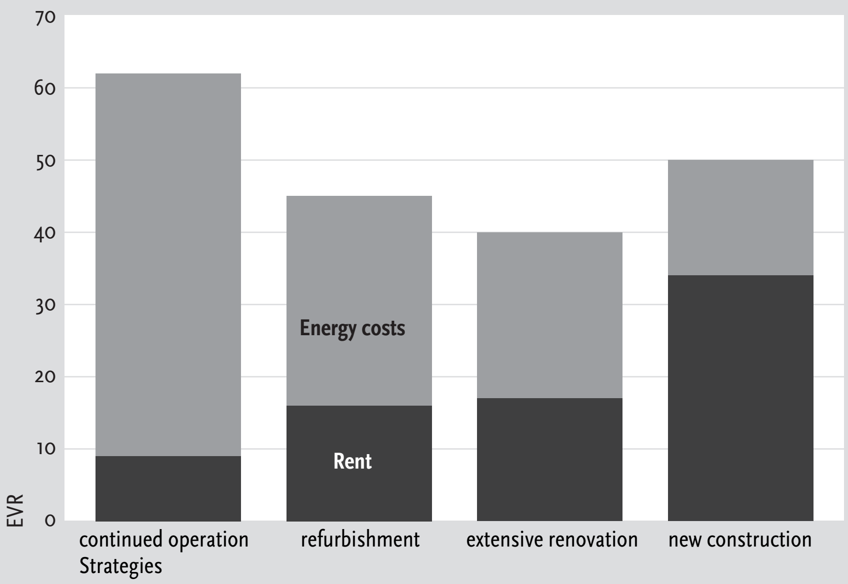
Apart from rent, housing expenses also consist of energy costs. The levels of energy costs following the varying interventions are assessed with help of the energy demand estimating tool (DGMR, 2004).

In a real-life feasibility study, the final evaluation of the various strategies could take place by comparing the results of the estimates with the findings of a customer value assessment. In this case study, however, all strategies are assumed to result in acceptable levels of housing expenses (for different target groups), in the traditional economic sense. In other words: the housing expenses of the varying apartments can be considered to represent the values of the provided housing services. So, in line with the model of the Eco-costs/Value Ratio (EVR), the environmental burden of the discerned strategies for interventions in the housing stock can be compared with their value by comparing them with the (traditional economic) housing expenses.

The EVR of refurbishment calculated this way, turns out to be lower than the EVR of an unchanged continued operation. As can be seen in Figure B, extensive renovation has an EVR, wich is even lower than that. The EVR of new construction turns out to be lower than the EVR of continued operation, but it is higher than the EVR of renovation.

Figure B also shows, which part of the EVR is due to the rent and which part to the energy costs. In the cases of refurbishment and renovation, a relatively

Figure B Eco-costs/Value Ratio of housing expenses at several strategies



larger part of the expenses consists of energy costs than in the case of new construction. These energy costs raise the Eco-costs/Value Ratios of refurbishment and renovation. However, they remain clearly below the EVR of new construction.

Tim de Jonge
Roosendaal, 2005

1 Introduction

This chapter offers an introduction in the problem field and deals with the research questions and the structure of the report.

1.1 Sustainability

In 1987 the World Commission on Environment and Development (WCED) proclaims the need for economic growth "… that is forceful and at the same time socially and environmentally sustainable". Within this context sustainable development is defined as "… development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (Brundtland, 1987). This definition of sustainable development is widely accepted and is also used in this thesis.

In its summary about sustainable development, the WCED concludes: "… in the end, sustainable development is not a fixed state of harmony, but rather a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are made consistent with future as well as present needs. We do not pretend that the process is easy or straightforward. Painful choices have to be made. Thus, in final analyses, sustainable development has to rest on political will." (Brundtland, 1987, p.9).

In 1995, the World Business Council for Sustainable Development (WBCSD) described the role for the industry in its definition of eco-efficiency as "the delivery of competitively priced goods and services that satisfy human needs and bring quality of life while progressively reducing ecological impacts and resource intensity, through the life cycle, to a level at least in line with earth's carrying capacity." (WBCSD, 1995).

1.2 Sustainability of the housing stock

When the sustainability issue is connected to planning and designing the living environment, one of the aspects to take into account is the condition of urban areas already existing at present. In major parts of Europe (and probably elsewhere) the large existing stock of houses and other buildings, has an impact on the qualities and potentials of the living environment. This impact is linked to the characteristics of the buildings, concerning questions like: are they (still) fit for use and what about their energy consumption?

The buildings also determine to a high degree the urban configuration by their very presence in the places they were once erected. In this respect, questions could be: does the orientation of the buildings allow them to benefit from sun energy or what is the effect of the spatial lay-out of neighbourhoods on commuting? and so on.

Last but not least, urban areas have to deal with another form of sustainability problems: the connection between socio-economic developments in the residents' groups of neighbourhoods and the durability of the existing urban structure. In the Netherlands for instance, after the Second World War an enormous amount of dwellings were built in new urban extensions. Approximately, one third of these dwellings consists of staircase-access flats of modest dimensions and quality. At the time of construction these flats were designated for mostly young families, but in the course of years the population of the neighbourhoods has changed. Driven by family development (children growing older and leaving their parental homes) and economic improvement the initial tenants' group has been replaced by newcomers: people with low income, often coming from foreign countries. Partly due to the relatively large scale of the neighbourhoods in question the evolved uneven composition of the population is now becoming a problem (Ekkers, 2002).

1.3 Sustainability in building development

Ever since the WCED-report was published, throughout the (industrial) world people have started to make efforts to produce in a more sustainable way than they used to do. In the building sector several initiatives have been made to improve sustainability on a practical level, as will be described in Chapter 2.

Researchers created decision-making tools to support architects and other participants in building projects, in particular on the subject of ecological burden of buildings. The best-known tools that have been developed for this purpose in the Netherlands are Eco-Quantum (IVAM, 1999) and Green-Calc (Van der Linden, 2002). However, one of the problems these tools suffer from is that they are not well integrated in the traditional development processes of building projects. In day to day practice of building development, they are often considered to be disturbing and time consuming obstacles (BNA, 2001 and BNA, 2002).

In order to implement sustainability issues in general decision-making referring to product design, research has been conducted to express ecological burden in economic terms. A theoretical framework to do so is presented in *The model of the Eco-costs/Value Ratio, a new LCA-based decision support tool.* (Vogtländer, 2001). One of the ideas of that study is to define eco-costs as: "virtual costs related to measures, which have to be taken to make (and recycle) a product in line with earth's carrying capacity". In the context of building development, eco-costs are the costs of (additional) measures, which should be carried out to reduce pollution, resource depletion and fossil energy consumption, caused by the projected construction activities and the use of the building, to a level that is sufficient to make society sustainable. Just like traditional costs, these eco-costs are balanced to the (aimed, expected or obtained) value of the plans concerned. However, in building development projects the decisions with the highest impact on economics and presumably also on ecology are considered to be taken in the very early stages of the development process (Bredero, 1975 and Kranendonk, 1999).

In these stages hardly any information on product specifications is available. Therefore, designers in the building sector need a tool that can estimate eco-costs in particular based on preliminary product specifications.

In addition, successful implementation of such a tool in day to day design practice can only be achieved if the required tool fits in well with the usual sequences in building development processes.

1.4 Sustainability interventions

As indicated in Section 1.2, the functional and technical suitability, as well as the spatial lay-out of the existing urban housing stock can be questioned as to ecological sustainability. In addition, the uneven composition of urban areas and their residents' groups bring problems concerning social sustainability. Which kind of solutions do we have to aim at? In recent years, the capacity of our building industry in terms of numbers of new housing development did not exceed the amount of just 1% of the stock (Thomsen, 2001). Therefore major redevelopment by demolition and new construction to solve urban (ecological) sustainability problems on a significant scale would need an enormous expansion of this industry. This is practically beyond economic feasibility and both the ecological and social sustainability of such an approach could be questioned.

To improve the sustainability of our living environment, research may be directed to determining the needed qualities of new building designs and urban forms. In addition to and maybe even prior to that, we should look for strategic measures in the existing urban areas, which are cost effective, in ecological as well as social and economic sense.

It is obvious that (the initiative and design stages of) renovation or redevelopment projects are the most suited moments to influence the sustainability of the housing stock. Whether the involved persons are aware or not, design decisions in building projects will influence the sustainability of the stock anyway. To improve ecological sustainability in the housing sector, directing decision support tools (like Eco-Quantum and Green-Calc) to the building design process seems the right thing to do. However, since the starting point should be the existing stock, tools should support decisions on questions like whether to renovate or to (demolish and) redevelop, in the first place. As will be shown in Chapter 2, the existing tools are not quite capable of producing valid answers to these very questions.

1.5 The aim of the research

The aim of the research for this thesis is to develop (a prototype of) a decision support tool for building development projects with the following characteristics:

- The tool can produce information on the environmental burden of housing projects, related to the design characteristics on all relevant scale levels, which are usually referred to in different project stages, starting in the phase of project definition and following the design process up to the specification phase.
- In any phase of the design and development process, in which the tool is used, the tool does not need input information on scale levels that are more detailed than the one that is common for that phase.
- The tool can be used in both new construction, redevelopment and renovation projects and can produce eco-information for decisions referring to whether to renovate or to redevelop.

1.6 Problem definition and research questions

This research is linked to the model of the Eco-costs/Value Ratio. It concerns the applicability of the model as a tool in design and decision-making processes preceding interventions in the housing stock. Therefore, the research problem definition reads:

Is estimating eco-costs and weighing them against intended value, on project level, a useful way of evaluating ex ante the ecological impact of (alternative) plans for interventions in the housing stock, in particular in the early stages of development processes?

This problem definition comprises the following research questions:
What is understood by 'eco-costs' and what is a practical way of estimating eco-costs for new building design and renovation plans?
The concept of 'eco-costs' in the context of sustainability and estimating eco-costs is dealt with in Chapter 2 'Eco-costs of housing'.

Assessing whether the estimated eco-costs are really 'worth while' by weighing them against the obtained (or rather the expected) value produces the second research question:
What is a meaningful approach of the concept of 'value' in the context of relating environmental burden to that 'value' as a result of design decisions concerning interventions in the housing stock?
This question is dealt with in Chapter 3 'The value of houses'.

The emphasis on alternative plans in the early stages of design and development processes produces the third research question:
What requirements are set by design and development processes for a decision-support tool referring to eco-costs in particular during the early process stages?
This question is dealt with in Chapter 4 'Design and development processes'.

Based on the research conclusions, a prototype is produced for an estimating model referring to both eco-costs and traditional construction and operating costs related to interventions in the housing stock. This model is evaluated on the basis of the final research question:
What can be expected from applying such a tool in terms of reducing the ecological burden of housing (in general and on project level)?
This part of the study is reported in Chapter 5 'The Eco-costs/Value Ratio of housing'.

1.7 Methodological explanation

In this thesis, research is focused on the intersection of economics and technology. Results of research in science are used, but the study in this thesis is not intended to explore or attribute to the science aspect of the sustainability issue. The research is structured as follows:

What is understood by 'eco-costs' and what is a practical way of estimating eco-costs for new building design and renovation plans?

Literature studies
In respect of the first research question literature is studied concerning existing knowledge and tools, which refer to quantifying ecological burden in general and in the building sector more specifically. From this literature conclusions are drawn referring to a practical way of quantifying ecological burden in the building sector.

Design and development
To show the feasibility of the selected approach an eco-cost estimating model is developed on the basis of three existing decision-support tools for building design and development projects:
- An estimating tool, which has been used for cost estimating in new construction and renovation projects for over 20 years (Winket, 2004).
- An estimating model for energy consumption, developed in commission of the Dutch Ministry of Housing, Spatial Planning and the Environment, to be used by architects in the design stage for improving the energy performance of buildings (DGMR, 2001).

- A tool for estimating the effects of design alternatives on maintenance costs, recently developed for educational purposes at the Faculty of Architecture at Delft University of Technology.

Empirical data research
To ensure that the construction costs data and the recipes of the elements in the estimating model can be considered as representative for (new construction and renovation) projects in the housing sector, detailed budget analyses are executed, based on the winning tenders of 60 recently completed building projects.

What is a meaningful approach of the concept of 'value' in the context of relating environmental burden to that 'value' as a result of design decisions concerning interventions in the housing stock?

Literature studies
In respect of the second research question literature is studied concerning the concepts of value and quality in general and of houses in particular. Special attention is given to the degradation (and recovering) of quality in time.

Design and development
In order to find an answer to the research question, the following models are designed:
- By integration of several ideas concerning aspects of value and quality, a conceptual model is developed referring to the relations between consumer quality and the value of houses.
- A (micro-)economic model for the life-cycle of houses is developed, in which value aspects, related to customer quality, are integrated with investment and operating costs referring to both traditional costs and eco-costs.

What requirements are set by design and development processes for a decision-support tool referring to eco-costs in particular during the early process stages?

Literature studies
In respect of the third research question literature is studied concerning design and development processes in the building sector in various countries. Since the model of the Eco-costs/Value Ratio is an estimating model in form and function, research is directed towards the questions:
- Which estimating methods have been developed to support design decisions in housing projects?
- What kinds of problems do these traditional estimating methods show in development practice?

Design and development
An eco-costs/value model for housing is developed, based on the concept of the EVR. Techniques used are so-called operating estimates.

1.8 Restrictions

The scope of this research is restricted to the optimisation of sustainability measures on the level of individual projects referring to interventions in the housing stock. This means that the research is aimed at offering comprehensible information to stakeholders in renovation or redevelopment projects in order to enable them to make choices that are in the right direction in terms of sustainability. This means that the research explicitly has not been involved in the development of alternative 'sustainable' products or materials. It also means that the research has not been aimed at estimating the total effect of these choices on a macro economic or 'macro ecological' level.

The research has been directed to the 'original' sustainability issues (pollution and depletion of the earth), which have a wider impact than just local and temporary effects. Consequently, the research has not been involved in issues related to land-use and to the conservation of nature (related to urban or spatial planning, planning of national parks, global master planning etc.). Also local health and safety issues are beyond the scope of the research (including the local damage of noise and smell, probabilities of accidents related to manufacturing facilities etc.).

All traditional cost data in the research refer to construction, renovation, refurbishment and operation of housing projects in the Netherlands, while the values for several eco-indicators refer to situations in the Netherlands (and the European Union).

The development of the decision support tools is considered to be completed as far as the conceptual model is concerned. Before the model can be presented as ready for use, several more preparations will be needed.

The operating estimates are prepared for reasons of comparison within the scenarios in this study; no research is done concerning the plausibility of applied values for the various parameters.

2 Eco-costs of housing

This chapter introduces the model of the Eco-costs/Value Ratio (EVR) and deals with the research question: what is the meaning of the concept of 'eco-costs' in the context of sustainability and what is a practical way to establish eco-costs of housing.

2.1 Introduction

The model of the Eco-costs/Value Ratio (EVR) has been developed as a decision-support tool concerning the sustainable production and use of products and services. This chapter starts with exploring the context in which the EVR model was introduced (Sections 2.2, 2.3, 2.4). Next, the study is directed to the question how the EVR model relates to other sustainability tools, especially in the construction industry (Section 2.5). Finally, research is focussed on the definition of eco-costs and the possibilities to develop a practical model for estimating eco-costs, using existing tools for construction cost calculation and energy demand estimation (Section 2.6).

2.2 Qualitative approach of sustainability

2.2.1 Qualitative approach in the Dutch construction industry

To promote designing for sustainable production, several tools have been developed from a qualitative point of view. In the Dutch construction industry, the most important tools in this category are the so-called National Sustainable Building Packages (NSBP), published by the Dutch National Sustainable Building Centre. The NSBP for Housing, referring to new building projects, appeared in 1996. The section Maintenance, for the sustainable maintenance of existing houses, and the NSBP for Utilities, followed in 1997. Finally, packages for urban development and for civil engineering projects appeared in 1999 (DUBO, 2003).

The aim of these packages is to offer building partners a basis for a clear definition of sustainable building, in general and in specific projects. According to the DUBO-organisation, Dutch building industry parties really seem to use these tools rather commonly. Local authorities have composed policy documents based on the packages and also some ambitious private clients have used these tools to formulate their project requirements.

2.2.2 The leading idea

The leading idea behind the qualitative approach is that environmentally responsible action is determined by the 'Trias Ecologica': prevent unnecessary use, use sustainable resources and use these resources in a sensible way (Duijvestein, 1998). For ease of survey in the NSBP, this environmentally responsible action is mainly focussed on four factors: location, design, materials and workmanship (DUBO, 2003).

- Location of a building, in its sense of social and cultural environment, natural habitat and scenic settings, is very important for the qualities and possibilities for use in the long term. Here the relation between building and surroundings plays a role, as for traffic flows, proximity of shops and other facilities etc.
- Design, in terms of lay-out and general appearance of a building, is of course important to make sure that for instance a dwelling is comfortable to live in, or that a factory is functional and offers healthy working conditions. The design of a building is a determinative factor for a lot of environmental effects. Solar orientation and the size of windows for instance are essential for implementing active or passive solar energy-systems. Flexibility of lay-out also influences sustainability: a design that anticipates future use or can easily be adapted to future requirements is preferable.
- The choice of materials clearly influences the environmental performance of buildings. However, a well-performing material in the context of a faulty design cannot realise its environmental potentials.
- Finally workmanship can make or break whatever design or well-performing materials.

2.3 Quantifying ecological burden

2.3.1 Life Cycle Assessment

In spite of the success of the qualitative approach, a need for a more quantitative approach has emerged, especially in the field of ecological burden as the result of the application of various materials. Think for instance of the depletion of materials, climate change, the depletion of the ozone layer, noise, dust etc. (Vogtländer, 2001).

The most systematic method in this field is the Life Cycle Assessment (LCA), as initially developed at Leiden University (CML) and published by the International Organization for Standardization (ISO). The LCA method aims at a systematic analysis of all environmental impacts of a product in all its stages of life (ISO, 1998).

LCA provides a systematic approach to measuring resource consumption and environmental releases to air, water and soil associated with products, processes and services. It takes into consideration that all product life cycle stages (extracting and processing raw materials, manufacturing, transportation and distribution, use/reuse, and recycling and waste management) have

Villa at Naaldwijk (new construction).

environmental and economic impacts.

LCA is intended to be a decision-making tool for governments and businesses. It is used to measure and compare the environmental impacts of products and services. Most LCA measurements are made by summing the units of energy consumed in extraction of raw materials, transport, manufacture, distribution and final disposal of a product or service. Additional calculations are made of emissions to air, land or water resulting from the creation and disposal of the product or service. LCA is also used to identify points within a product's life cycle where the greatest reduction in resource requirements and emissions can be achieved.

According to the ISO 14040 series standards, LCA should assess the potential environmental aspects associated with a product or service by:

- compiling an inventory of relevant inputs and outputs;
- evaluating the potential environmental impacts associated with those inputs and outputs;
- interpreting the results of the inventory and impact phases in relation to the objectives of the study.

2.3.2 Limitations

LCA has some limitations: a great deal of basic research must be completed to establish baselines with which to compare environmental impacts. In addition, impacts will vary per region, so it can be very difficult to compare products made in different countries (NDRC, 2004 and ISO/TC207, 2004).

In summary, LCA as a tool for sustainability assessment of products, services or functions has been almost fully developed. Only some details in the ISO definitions are still under discussion. So, from a scientific point of view the ecological burden of products could best be assessed by LCA calculations according to the ISO norm 14041. As LCA describes a very complex problem, the method itself is very complex as well. Executing LCA costs a lot of time and money, while many data have to be gathered and processed. The result of LCA comprises a multitude of environmental impact figures, which have to be interpreted again and weighted to draw the conclusion if one product is better or worse than an alternative product.

As a result LCA is often considered to be too complicated and specialised to serve as a decision-making tool in development projects. Only environmental experts are able to interpret them, and even their complex decisions are not easy to communicate to the stakeholders in development projects.

2.4 A single eco-indicator

2.4.1 The need for a single indicator

How should the results of two different LCA studies be compared? And how should the results of LCA be communicated to people other than the environmental specialists? These issues get gradually more important as the results of LCA studies have to be communicated to the stakeholders in development projects. They need clear and comprehensible information to know which decisions are in the right direction in terms of sustainability (in matters of legislation, product and production specifications and consumer expenditures).

As to emissions, the impact of emissions will not show up directly, but only in the long term, when it is too late to do something about it. In order to enable the stakeholders to make the right decisions that will support a sustainable society, one yardstick is required for emissions.

As to the depletion of materials, it is not immediately clear which one is the best choice if it comes to using either one of two different scarce materials. So, also one yardstick is required to measure the depletion of materials.

The effects of emissions and the depletion of materials will have to be balanced against the environmental burden of energy consumption, labour and the use of equipment e.g. for assembling, maintenance and dismantling activities (Vogtländer, 2001).

2.4.2 A single indicator for emissions

A generally accepted route towards a single indicator for the effect of emissions is an approach which is based on splitting the problem into two levels (ISO 14040):

- combining emissions with the same nature of effect: the so-called classification in groups; followed by weighting the importance of an emission within each class: the so-called characterisation within the group. For each group this leads to an 'equivalent weight of the major pollutant in the class';
- finding a weighting principle to add up the different classes.

Refurbishment and renovation project at Nijmegen.

For most of the major pollutants, the classification and characterisation factors can be assessed from the chemical, physical or biological effect they have: acidification, eutrophication, summer smog, winter smog, heavy metals, carcinogenics and global warming. Though not all problems in assessing sustainable levels for these effects have been solved yet, the relative weight within all different classes can be assessed (Vogtländer, 2001).

Finding a weighting principle to add up the effects in the different classes is quite another problem, as the chemical, physical and biological characteristics of the discerned classes differ greatly.

In principal there are three ways to weight varying types of potential damage:

- weight the negative value of the damage (the 'impact');
- weight the required effort to prevent the damage;
- weight the required effort to 'repair' the damage.

The third option is generally not the desired option for sustainability problems, since 'repair' of emissions is either much more expensive than prevention or not possible at all. (Examples of 'repair' are the attempts to restore the loss of biodiversity in town and country planning). So weighting the classes can either be done according to impact (type 1) or prevention (type 2). The weight of both impact and prevention can be expressed in 'points' or in 'money'.

The vast majority of the models for a single indicator is based on the combination of impact and points, as will be shown in the next section. Models for weighting based on impact (damage) have two fundamental problems:

- weighting the impact is a very subjective and arbitrary matter: how to compare a fatal illness to dying trees and/or species going extinct? (Finnveden, 1997);
- an assumption in damage based models is that the damage is proportional to the concentration and to the emissions, which is far from reality (Vogtländer, 2000).

The main argument to apply a prevention based model is of a practical nature: Knowing that prevention is the required route towards a sustainable society, why weight on the basis of impact? (Shouldn't we prevent rather than accept the damage?) In other words, weighting sustainability effects based on impact could be mentioned 'awareness driven' while weighting effects based on prevention efforts could be mentioned 'action driven'. However, models for weighting, based on prevention, suffer from the problem of setting the sustainable norms for emissions. (To what level do we have to reduce emissions to reach a sustainable situation?)

2.4.3 Expressing weight in points or money

As mentioned above, the weight of both impact and prevention can be expressed in 'points' or in 'money'. The advantage of using 'money' is that sustainability effects can be weighed against other (money-costing) characteristics of a product. Another argument is that decision-makers in (building) industry (and the public in general) are used to think in terms of money. As decision-support tools are made for communicating eco-effects to decision-makers in the first place, this should also plea for the application of 'money' as an expression. To many people these advantages are disadvantages: because of the assumed irreversibility of many ecological effects, these effects should not be traded off against other product characteristics.

It is evident that a perfect and generally supported weighting principle does not exist. However, (the few) prevention based models tend to use 'money' as a means to indicate the potential ecological damage of a product. Maybe they do so, because these models have to deal with the (more or less arbitrary) decisions to which level reduction of emissions can be considered sustainable, anyhow. Assessing the costs of measures to reach these reductions is actually just a matter of formalising decisions already made.

2.5 Existing models for the building industry

2.5.1 Selection criteria

Many calculation models, which can assess the environmental quality of building products, buildings and built environments, have been developed. Approximately 30 models have been looked at for this study (references at Table 2.1). They all have slightly different goals and scopes. Half of these models are LCA based. Not all of them offer a single indicator. Many models present their output in the form of separate indicators for several effect categories.

Table 2.1 Tools for eco assessment of (complete) buildings and some characteristics of these tools

		LCA based	Single-indicator	Weight based on	
				damage	prevention
France	Equer	x	-	-	-
Germany	Ecopro/Legoe	x	-	-	-
Netherlands	Eco-Quantum	x	x	x	-
Netherlands	EVR	x	x	-	x
Netherlands	Green-Calc	x	x	-	x
United Kingdom	Envest	-	x	x	-

Sources:
Bauhaus-Universität Weimar: Tabelle, www.uni-weimar.de/scc/PRO/TOOLS/tabelle.xls.
Department of the Environment and Heritage, *Greening the Building Life Cycle, Life Cycle Assessment Tools in Building and Construction, Building LCA Tools description*, http://buildlca.rmit.edu.au/.
IVAM, W/E adviseurs duurzaam bouwen, 1999, Eco-Quantum, SBR and SEV, Rotterdam.
IVAM, 2003, Eco-Quantum, www.ivambv.uva.nl.
Linden, K. van der, et al., 2002, *GreenCalc, een calculatie- en communicatiemodel om milieubelasting van gebouwen meetbaar en vergelijkbaar te maken*, Stichting Sureac.
www.greencalc.com/greencalc/
Vogtländer, Joost, 2001, *The model of the Eco-costs/Value Ratio, A new LCA based decision support tool*, thesis, Delft University of Technology (Delft).
www.eere.energy.gov/buildings/tools_directory/software/envest.htm
www.bre.co.uk/service
www.eere.energy.gov/buildings/tools_directory/software/equer

Apart from practical reasons, the following arguments are brought up to select models for more detailed review:

- LCA based models are preferred because of the systematic character of this approach as described in Section 2.3. Non-LCA based models are considered to be of less interest for this research, unless they show major advantages in respect to the approach of design and development processes. A preliminary review showed that none of the models that were non-LCA based, showed major particularities in respect to the approach of design and development processes. They all showed either building shapes, elements or materials oriented approaches.
- Whereas the LCA results may differ for different regions (Lützkendorf, 2002 and NDRC, 2004), for the Dutch situation, the emphasis should primarily be on West European models. As for the models, which are directed to complete buildings, this argument provides the selection as shown in Table 2.1. Since the basis for the Envest model does not include LCA, this model has not been investigated in more detail.
- Models that provide single-indicator output are preferred, as discussed in Section 2.4. Because Equer and Ecopro/Legoe do not provide pre-established weighting of various ecological effects, no further research has been done on these models.
- Because of the considerable problems to set weighting standards based on

damage/impact, as discussed in Section 2.4.3, and because of the advantages of prevention based models that use 'money' as an indicator in respect of communicating eco-effects, as mentioned in Section 2.4.4, the latter types of models are preferred. This would leave only EVR and Green-Calc for further research. However, while Eco-Quantum is probably the best known instrument for assessing ecological burden of dwellings in the Netherlands, this model is discussed all the same.

2.5.2 Eco-Quantum

For the housing sector SBR (Dutch Building Research Foundation) and SEV (Steering Committee for Experiments in Public Housing) have developed Eco-Quantum. This programme has been made to offer architects an insight in the environmental impacts of design alternatives for new housing developments. In Eco-Quantum, the environmental performance of a dwelling is defined by combining the effects of the use of materials in construction elements, energy consumption through mechanical and electrical systems (related to heating, indoor climate in general, and warm water supply), water consumption (as such) and the building's location. Eco-Quantum is based on LCA data that come from MRPI. MRPI is the Dutch abbreviation of Environmental Relevant Product Information, which stands for: "reviewed information about the environmental aspects of a building material, building product or building module, based on an environmental life cycle assessment (LCA) and initiated by the manufacturer or his representative" (IVAM, 2003 and MRPI, 2003).

Architects may complete input in 6 different levels to use the programme: dwelling, building parts, elements, components, component alternatives and sub-alternatives. Required input is comparable to what is required for making a specified elemental bill of quantities. Once the architect has assessed the input for the first design, it is rather easy for him to rearrange the input data to make calculations for similar designs in a project.

Eco-Quantum can show output in three forms. It can present environmental impacts (of elements or the whole building) in 12 categories: depletion of materials, depletion of fuel, greenhouse effect, ozone layer depletion, summer smog, humane toxicity, water toxicity, acidification, eutrophication, non-renewable energy, waste and dangerous waste. It can also summarise this output to environmental indicators referring to: raw materials, emissions, energy and waste. Finally a single Eco-indicator can be calculated that compares weighted environmental performances of the design with a well-defined reference dwelling. The idea is that calculation of different alternatives of the same building results in a clear comparison for ecological burden, which can be used by architects to optimise the environmental terms of their design.

Eco-indicator = $D_{Assessed}/D_{Reference}$

$D_{Assessed}$ represents weighted damage caused by assessed dwelling.
$D_{Reference}$ represents weighted damage caused by reference dwelling.

A lower value of the indicator indicates a better environmental performance of the assessed dwelling.

2.5.3 Green-Calc

For the non-residential sector DGMR Consulting Engineers and Stichting Sureac (Sureac Trust) have developed Green-Calc. This tool claims to support decision-making right from the initiatory phase of a project. In the initiatory phase this results in defining targets in an 'environmental budget'. Architects may use Green-Calc to compare design alternatives and to assess alternatives to targets. After the project is constructed, the model may be used to evaluate, whether the targets have been met (Van der Linden et al., 2002 and Haas, 1997).

In the Green-Calc model, architects start defining a project, in which they may make different building designs. A once contrived design may be duplicated and modified in order to make an alternative design in a rather simple way. Within a design, the architect may set up one or more scenarios referring to the application of various materials and building services. Input procedures are more or less comparable with those of Eco-Quantum. In Green-Calc, the energy performance section and the location impact section are more elaborated. This may be related to the fact that service systems tend to be more complex in offices and that commuting may be an object of decision-making in office development projects.

The output of Green-Calc is presented in the form of 'hidden environmental costs' and an 'environmental index'. The hidden environmental costs are defined as all-in costs, expressed in money, for prevention (or in some cases repair) of environmental damage caused by construction and operation of the building. The environmental index compares the hidden environmental costs of a reference building to the hidden environmental costs of the assessed building. The reference building is the same building as the assessed building except for applied materials and techniques. The materials and techniques in the reference building are dated in 1990. The advantage of the environmental index is the possibility of comparing buildings with various dimensions.

Environmental index = $C_{Reference}/C_{Assessed}$

$C_{Reference}$ represents the environmental costs of the reference building.
$C_{Assessed}$ represents the environmental costs of the assessed building.

Figure 2.1 The EVR-chain, combining the economic and ecological chain

Value:	**value**	+	**Δ value**	+	**Δ value**	+	**Δ value**	+	**Δ value**	+	**Δ value**	**= Total value**
	Materials		Semi-finished products		End products		Distribution		Use		End of life	
Costs:	**costs**	+	**costs**	+	**costs**	+	**costs**	+	**costs**	+	**costs**	**= Total costs**
Eco-costs:	**eco-costs**	+	**eco-costs**	+	**eco-costs**	+	**eco-costs**	+	**eco-costs**	+	**eco-costs**	**= Total eco-costs**

Source: Vogtländer, 2001

A higher value of the index indicates a better environmental performance of the assessed building.

2.5.4 The Eco-costs/Value Ratio (EVR)

At Delft University of Technology, research has been done to express ecological burden in economic terms. Vogtländer describes a theoretical framework to do so in 'The model of the Eco-costs/Value Ratio, a new LCA based decision support tool'. The basic idea of the EVR model is to link the value chain (Porter, 1985) to the ecological product chain (see Figure 2.1). In the value chain, the added value in terms of money and the added costs are determined for each step of the product 'from cradle to grave'. Similarly, the ecological effects of each step in the product chain are expressed in terms of money: the so-called eco-costs (Vogtländer, 2001).

Characteristic of each process, product or service is the ratio of the value and the eco-costs. This Eco-costs/Value Ratio (EVR) can be defined at any aggregation level of the chain as follows:

EVR = eco-costs/value.

A low EVR indicates that the product is fit for use in a future sustainable society. A high EVR indicates that the value/costs ratio of a product might become 'less than one' in the future, since 'external' costs will become part of the 'internal' cost-structure. This means that there is no market for such a product in the future (Vogtländer, 2001).

2.5.5 Discussion

Three LCA based models for assessing environmental impact of buildings have been selected for research concerning their applicability to support development decisions in early design stages. Eco-Quantum uses a damage based weighting principle, which has some disadvantages as discussed before. Green-Calc and EVR apply the favourable prevention based weighting principles. But what are the advantages and disadvantages of the various

Example of comparing new construction to renovation

Suppose the value V_N of a new building N is 10% higher than the value V_R of renovated building R, and the eco-costs E_N of new building N are 30% higher than the eco-costs E_R of renovated building R.

In formula: $V_N = 1.10 \times V_R$ and $E_N = 1.30 \times E_R$

So: $EVR_N = E_N/V_N = (1.30 \times E_R)/(1.10 \times V_R) = 1.18 \times E_R/V_R = 1.18 \times EVR_R$

Starting from the presented assumptions, the EVR of the new building N is 18% higher than the EVR of the renovated building R. So, from the viewpoint of reducing environmental impact, renovation R would be preferable to new building N.

applied single indicators?

In Eco-Quantum the Eco-indicator compares dwellings to a fixed (and well defined) reference dwelling. This will do for assessing dwellings as long as the reference dwelling will remain a meaningful concept to the involved architects and decision-makers. Therefore, a periodical update of the reference dwelling may be required. The concept of the indicator induces that not only eco-effects of applied materials and techniques are covered by the assessment, but also eco-effects of alterations in building form. The actual elaboration of the model causes that buildings other than dwellings cannot be assessed by means of the model. However, the concept of the model allows assessment of other building types and renovation. But comparing the eco-effects of different building types or comparing new construction to renovation are not possible on the basis of this principle, let alone comparing the eco-effects of building investments to those of other expenditures.

In Green-Calc the Environmental index compares a building to a reference building in the same category and based on the same functional and formal design. So, this index neither covers the eco-effects of shifting building types nor the eco-effects of altering building form. It only will express the effects of using various materials and techniques. Indeed, also on the basis of this concept comparing new construction to renovation and comparing building investments to other expenditures are not possible.

The EVR compares the eco-costs of a certain product or product-service system to its value. The concept of EVR is independent from the type of product. However, it is essential that the product or system can be valued. So, in principle it supports assessments of all kinds of buildings, as long as the values of the buildings are comparable. Moreover, on that very basis, it allows comparing new construction to renovation or maintenance. As in particular this last characteristic has been required in the problem definition, further research will focus on the possibilities of EVR.

The two central concepts of the EVR model, 'eco-costs' and 'value', need further exploration in order to investigate the possibilities of using the model in the housing sector. The next sections in this chapter deal with 'eco-costs'. The concept of 'value' will be explored in the following chapter.

2.6 Eco-costs

2.6.1 Eco-costs in the EVR model

One of the central concepts of the EVR model is defining eco-costs as 'virtual' costs related to measures, which have to be taken to make (and recycle) a product 'in line with earth's carrying capacity'. In other words, eco-costs are the costs of technical measures to prevent pollution and resource depletion to a level, which is sufficient to make society sustainable. More specifically, the model is based on the virtual eco-costs '99 being the sum of the marginal prevention costs of the depletion of materials (1), energy consumption (2), toxic emissions (3), labour (4) and depreciation (5).

Marginal prevention costs are defined as the costs of the last and most expensive measures, which are assumed to be sufficient to create a sustainable situation in a given region. ('If we had taken these measures now, we would expectedly have had a sustainable situation.') The concept relates to the idea of applying the 'best practice' for sustainability in terms of technical feasibility and economic optimum. This approach requires that the best practice will be applied in a total region (in order to keep the industrial competitive playing field levelled), regardless of the fact that parts of that region could cope with less than the best practice.

1. Depletion of materials

The eco-costs (i.e. the marginal prevention costs) of the depletion of materials are set equal to the market value of the raw materials when the materials are not recycled. When a fraction a of the source material is recycled, a factor (1-a) is applied to this market value:

Materials depletion cost = 'market value of the raw materialial' x (1-a)

In theory, the costs of preventing depletion of a certain material are equal to the present market value of the 'sustainable alternative in the future' for that material (Pearce et al., 1990 and Henley et al., 1997 in Vogtländer, 2001). In the construction industry, depletion of materials mainly refers to metals and crude oil (for plastics). The functionality of most metals can be replaced by alternatives that are not more expensive for their specific functions. Therefore, there is no reason to believe that the present market value of the 'sustainable alternative in future' deviates much from the current average material prices (For instance, lead flashing as a damp barrier can be replaced by synthetic foil for similar costs).

Assuming that the (average) market value of the raw material for metals reflects whether the material is scarce or hard to find or mine (e.g. gold, silver), or whether that will happen in the foreseeable future, the eco-costs of

Marginal prevention costs

In the model of the Eco-costs/Value ratio, the marginal prevention costs have been chosen as a norm. In theory it is also possible to take the total prevention costs as a norm.

"There are 3 methodological reasons to take the marginal costs as a norm: The marginal costs are more stable in time (during the transition towards a sustainable society) than the total costs, so the bases on which calculations are made do not change during such a transition. The marginal costs are an estimation of future taxes or tradable emission rights, related to individual products in the event that nothing is done to prevent the related emissions; the marginal prevention costs are therefore relevant for product strategies of designers and business managers. The marginal costs are related to specific prevention measures (best available technologies), one for each class of emissions, which makes it plausible that the same marginal prevention costs will apply – in the long run – to all EEC member states." (Vogtländer, 2001 p. 169).

Using the idea of marginal prevention costs, however, implies that the eco-costs in the EVR model cannot be added up to calculate the 'grand total costs of prevention'. In order to produce macro economic estimates (e.g. Gerlagh et al., 2002), other concepts are needed.

depletion for metals are set equal to the market value of the raw materials. For plastics however, the price of biomass (as a source material instead of crude oil) has been chosen for the depletion costs.

2. Energy consumption

The calculation method to determine the eco-costs of energy is based on the assumption that fossil fuels have to be replaced by sustainable energy sources. So, the 'eco-costs of energy' are set as the price of renewable energy.

These eco-costs of energy mainly refer to the energy that is used for operating the product, e.g. in the housing sector the energy for heating and air conditioning. As an LCA provides data on both energy and its related emissions, the conversion to the related eco-costs has to be done carefully, to prevent counting energy twice. Since the eco-costs of energy have less spread in the calculations than the pollution prevention costs related to energy, eco-costs of energy should be used preferably in the conversion of LCA data to eco-costs. For the processing of materials, however, the use of fossil fuels is often highly integrated in the production process, so that the energy related emissions have to be applied instead (Vogtländer, 2001 p. 32).

3. Toxic emissions

For the prevention of toxic emissions, in the EVR model, the marginal prevention costs have been assessed for the seven emission effect classes (as mentioned in 2.4.3) on the basis of prevention measures, which are based on readily available technologies. The costs of the measures in the EVR model are determined on West European price level, dated 1999. The set of thus assessed costs is called the virtual pollution prevention costs '99 (see Table 2.2) (Vogtländer et al., 2000).

Apart from the 'original' pollution prevention costs, EVR also specifies the eco-costs of land fill, being the costs of prevention of land fill. Or, more specifically, the costs of the marginal prevention measures to reach the target for reduction of land fill, as set by the Dutch government (Vogtländer, 2001, p. 50).

Table 2.2 Virtual pollution prevention costs '99

6.40	Euro/kg	SO_X equivalent for acidification
3.05	Euro/kg	PO_4 equivalent for eutrophicatio
3.00	Euro/kg	VOC equivalent for summer smog*)
12.30	Euro/kg	fine dust for winter smog
680.00	Euro/kg	Zn equivalent for heavy metals
12.30	Euro/kg	PAH equivalent for carcinogenics
0.11	Euro/kg	CO_2 equivalent for global warming (Euro 114/1,000 kg)

**) Corrected figure, based on additional information Vogtländer, 2004.*

Source: Vogtländer, 2001

Table 2.3 Eco-costs of land fill

0.10	Euro/kg	Land fill materials

Source: Vogtländer, 2001

Table 2.4 Eco-costs/Value Ratio of labour

Types of labour	EVR
Personnel in offices	0.10
Personnel outside offices	0.05 – 0.15
Construction workers	0.12

Source: Vogtländer, 2001 and appendix 1

4. Environmental burden of labour

The eco-costs of labour are indirect eco-costs, since labour as such is hardly causing any environmental burden. However, the conditions related to labour, such as heating, lighting, commuting or (personal) equipment, do cause some environmental burden. In many situations the required labour for a product or a service is not known in terms of working hours, but just in figures of money. Therefore, instead of using eco-costs per man-hour for calculations, applying EVR (eco-costs/labour-costs) often is much more practical.

EVR calculations have been made for labour in offices and for personnel outside offices (see Table 2.4) (Vogtländer, 2001). An estimation of EVR for construction workers is added in this study (see Appendix 1).

5. Environmental burden of depreciation (use) of equipment, buildings etc.

Also the eco-costs related to the fact that fixed assets are used to make a product, are indirect eco-costs. The calculations on the eco-costs of the use of fixed assets have the same characteristics as cost estimates for investments.

In calculations for the building industry, apart from equipment for specific construction activities (like a mobile crane, a concrete formwork or a masonry saw), depreciation is usually presented in two forms: (general) building site costs and overheads. What is described as building site costs, usually covers a bundle of rather varying cost components. The contribution of the various components may differ according to the type of project. For estimations based on EVR, three groups of cost factors have been discerned within the

Table 2.5 Eco-costs/Value Ratio of building site costs and overheads*)

Cost factors	EVR
Site facilities and general equipment	0.10
Transportation	0.85
Site management	0.10
Overheads in the building sector (medium sized company)	0.14

**) See appendix 2.*

building site costs: site facilities and equipment (1), transportation (2), management (3).

Overheads in calculations for the building industry usually are expressed as an additional percentage to the direct building costs. In this study EVR for overheads is estimated based on a theoretical costing model referring to a medium-sized building company (see Table 2.5).

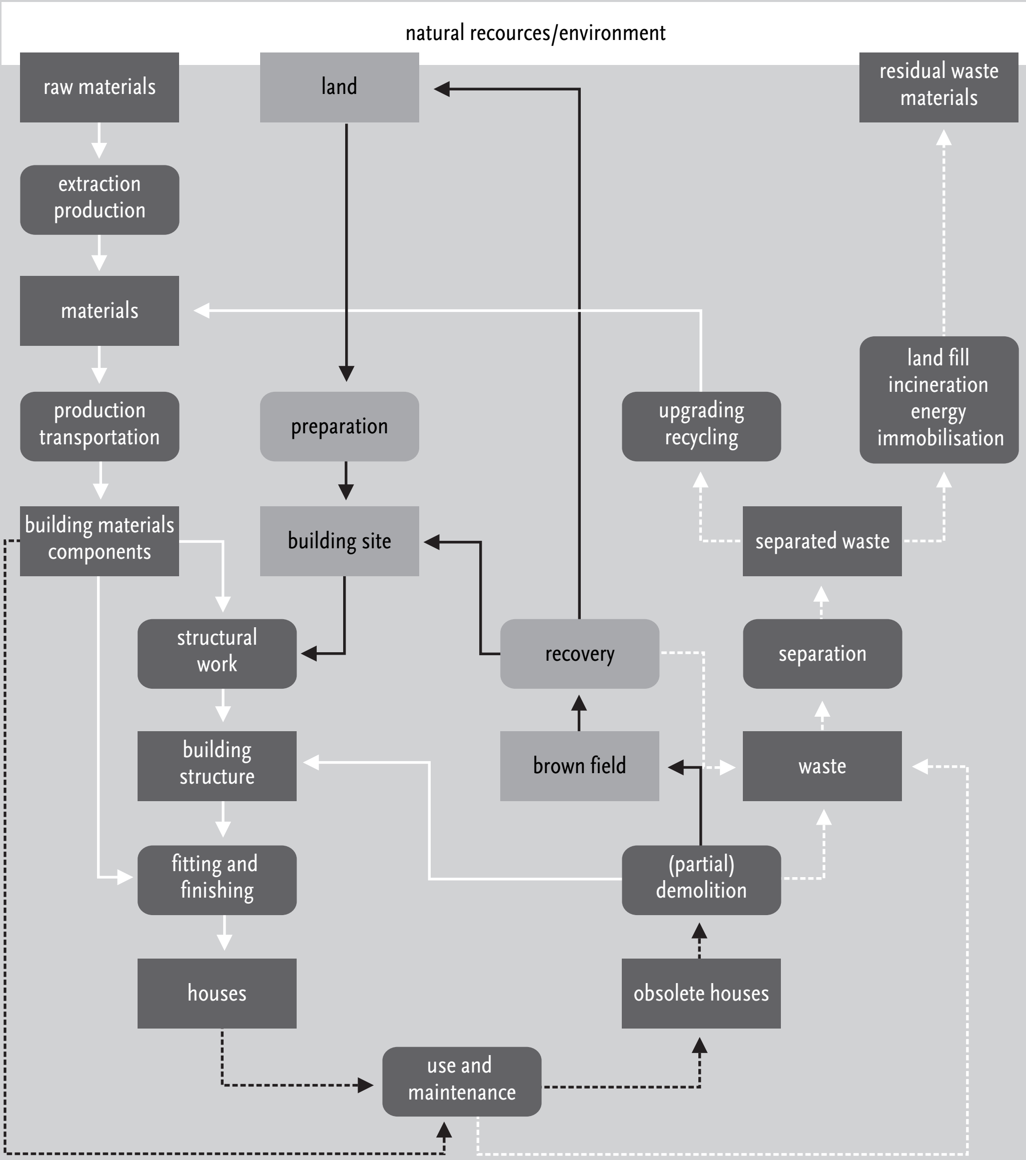
2.6.2 System boundaries and the phases in the life cycle of housing

In the previous section, the general approach of the sustainability question through the EVR model has been described. What, however, are the system boundaries of this approach when it comes to housing? In this thesis, the ecological burden related to housing is considered to refer to the materials depletion, energy consumption, emissions, labour and depreciation involved with the following aspects:

- construction (either new construction or renovation);
- maintenance and energy for heating, air conditioning and lighting and hot water supply (related to 'normal' housing activities during the operating phase);
- management and administration involved with letting activities (for rented houses);
- demolition and recycling of the obsolete dwelling (in the end of life phase).

Like all models based on LCA do, the EVR model includes the whole life cycle of a product. In case of houses or other buildings, at least three phases of the product should be discerned to look at in particular: the production phase, the operating phase and the end-of-life phase. Figure 2.2 represents a model of materials flow and land conversion in the life cycle of housing. The model is an input/output relations model that discerns materials and products from activities. In all stages of the materials flow, materials and products are considered as input and/or output of activities. For instance 'materials' are input for the 'production and transportation' activities, which produce 'building materials and components' as output. (Likewise, 'land' is considered as input for 'preparation', which has as output the 'building site'. In this scheme, land conversion activities and products are depicted in a very simplified way for clarity reasons. Apart from some qualitative remarks, the ecological impact of

Figure 2.2 Materials flow and land conversion in the life-cycle of housing



Legend

- Materials, products
- Activities; note that activities need energy and produce emissions, which aren't shown
- Land in several forms
- Land conversion activities; note that activities need energy and produce emissions, which aren't shown
- Input/output relations concerning materials flow in construction phase; either new buildings or renovation
- Input/output relations concerning materials flow in operating phase
- Input/output relations concerning materials flow in recycling/end-of-life phase
- Input/output relations concerning land conversion

land conversion is beyond the scope of this study.)

The upper-left section in Figure 2.2, characterised by solid white arrows, represents the production phase. The lower section with dashed black arrows represents the operating phase and the upper-right section with dashed white arrows the end-of-life phase. In the middle, the land conversion cycle is represented by solid black arrows.

2.6.3 Eco-costs of housing in the production phase

The materials flow in the production phase starts with the extraction of raw materials, like iron- and copper-ore and like stone, sand and cement. Also the production of basically reproducible materials like wood (growing trees) can be situated at this starting-point of the production phase of housing. After a series of industrial activities and transportations the materials flow arrives at the building site, where, by means of structural work, building materials and components are converted into a building structure. In a fitting and finishing process, in which again more building materials are applied, this building structure is finally converted into a house (or a residential building).

Note (in Figure 2.2) that recycled or upgraded waste materials from demolished former buildings (or other obsolete products) may be incorporated into the materials flow. The ecological effects of upgrading and recycling activities are counted as eco-costs in the production phase. Especially for materials depletion costs this already has been explained in Section 2.6.1.

Note also that – in case of renovation or refurbishment – the production phase includes activities concerning partial demolition of the existing building. Such a partially demolished existing building can be considered as a new building structure which is to be (re-)completed into a new house by fitting and finishing.

Note also that the materials flow of housing is connected to the materials flows of several other products and service systems, which is not depicted in the scheme for reasons of clarity.

Since estimates of traditional economic costs in most building development projects are set up as elemental bills of quantities, applying the same structure for estimating eco-costs would be very convenient. In this context, an important characteristic of building projects is that every project consists of a (tailor-made) combination of semi-finished products, which are assembled at the building site. Therefore, the environmental burden (the eco-costs) of a building in the production phase may be considered as consisting of the eco-costs of those semi-finished products plus the eco-costs of the assembling activities (including all the additional works like preparation works, building site facilities and management).

So, in principle it is possible to estimate the eco-costs of a building applying 'eco-cost unit prices' of building elements. As is done in a traditional cost estimate based on unit prices, the composition of the concerned elements is determined in terms of quantities of characteristic semi-finished products and assembling activities. For these products and activities, the emission and depletion data, which serve as a basis for eco-costs assessments, can be found in databases like IDEMAT (DUT, 2002), Eco-Invent (Pré Consultants, 2004) and MARKAL (Seebregts et al., 2004).

Hence, the eco-costs per unit of element can be determined by inserting the eco-costs of the semi-finished products and the assembling activities into the recipes of the elements. Finally, the elemental bills of quantities (for estimating traditional economic costs) can be converted into eco-costs estimates by substituting eco-cost unit prices for the traditional economic unit prices.

In order to test the possibilities of the described approach, eco-costs have been designated in this way to some 1000 calculation items in an estimating model for new construction and renovation, which is based on the NEN 2634 elements classification (Winket, 2004 and NEN, 1999). Further details on this subject are presented in Chapter 4 and 5. A survey of used eco-cost data is presented in Appendix 3. To ensure that the construction cost data and the recipes of the elements in the estimating model can be considered as representative for (new construction and renovation) projects in the housing sector, detailed budget analyses have been executed based on the winning tenders of 60 recently completed building projects. The empirical data from the reviewed tenders have been compared to the analytical composed cost data in the estimating model (De Jonge and Zonneveld, 2004).

2.6.4 Eco-costs of housing in the operating phase

In Figure 2.2, the operating phase is depicted as a single activity box, called 'use and maintenance', with four input/output relations. This may be slightly disguising, since in terms of eco-costs the operating phase appears to be very important, as will be shown in Chapter 3.

In the operating phase, a dwelling cannot be considered to be an addition of semi-finished products any more. The characteristics of a dwelling are not just determined by the characteristics of the components, but indeed also by the specific way in which they are assembled. The lay-out of a house, for instance, may be of more importance than the exact number of square metres of floor space, the orientation of a window may influence the appreciation of a room more than the size of the window. In the operating phase, a dwelling as a whole is understood as a system, which provides services on the one hand and needs energy and maintenance to do so on the other hand.

The provided services and the assessment problems evolving from the long lifetime of buildings will be discussed in Chapter 3 (Section 3.4 and further). The needed energy and maintenance, being related to the ecological burden of houses, are dealt with in the next sections.

2.6.5 Energy demand

The assessment of environmental impacts, associated with the operating phase, is usually based on many assumptions (scenarios) and calculation methods. The process primarily involves an inventory of the energy usage, which is necessary to run the building when in use, including heating, cooling, water heating, lighting, ventilation, lifts and other technical services. Scenarios forecast the type and duration of usage, the user requirements and standards of thermal comfort, location of the building, climate and intensity of use. These types of assumptions are often calculated according to predetermined default values and calculation methods, which are nationally uniform (Lützkendorf, 2002).

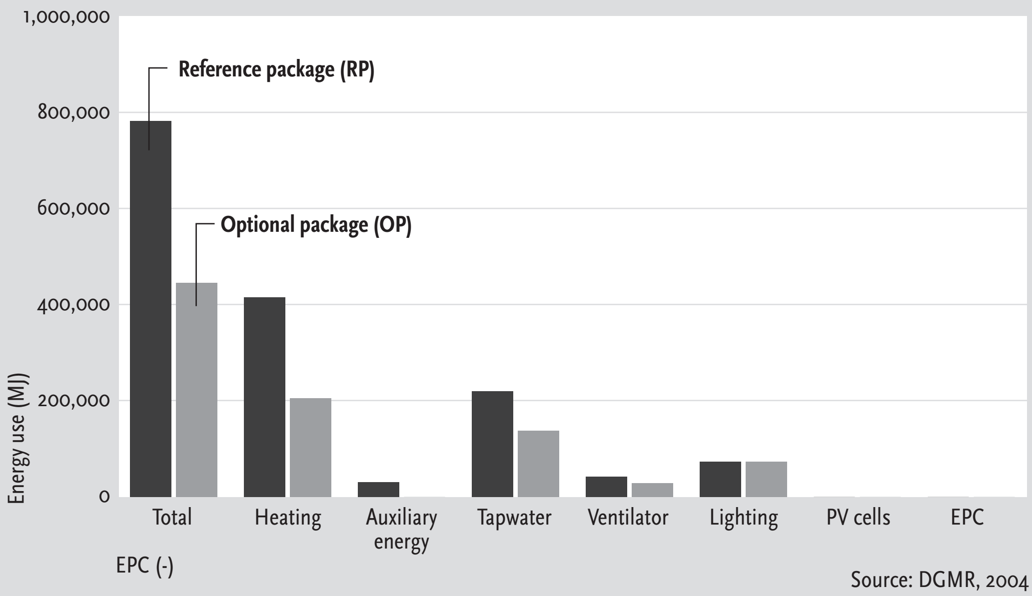
It should be kept in mind that the energy demand for heating and cooling systems, for instance, is heavily affected by user dependent influences. How many people live in the concerned dwelling, are they at home or out during day time, do they use warmth producing instruments etc.? These factors may most probably change over the lifetime of the building. In projects, which are aimed at reducing energy demand by specific (heating, cooling or lighting) systems, detailed research should be done, taking all variables in consideration including the expected lifetime of the systems (which is in general shorter than the lifetime of the building).

In 'day-to-day' housing development projects, however, a less detailed approach might be favourable. In these projects the approach of the energy problem comprises optimising lay-out and orientation characteristics of the building, the physical performances of available building components (e.g. insulation performances of walls and windows) and the service systems as the industry is offering them. In designing a residential building with its systems, it may even be wise to overlook the impact of the behaviour of a specific client or target group, as the useful life of the building usually exceeds the occupancy time of that client or target group. Such a more general approach as for lay-out, orientation etc. could be combined with special attention for possibilities to adjust the various systems' settings to specific behaviour.

In the Netherlands, for legal reasons (Buildings Decree 2003), energy demand of buildings is usually calculated according to NEN 5128:2004 (NEN, 2004). For applications in the design stage, based on this determination method, a spreadsheet for calculating the energy demand of residential buildings has been developed (DGMR, 2004).

This spreadsheet calculates the energy demand of a dwelling in general as well as specified for heating, auxiliary energy, hot water, ventilation, lighting and ('negative demand' from) PV-cells. The required input is limited, which enhances the applicability for decision-making in design. The input comprises rather basic quantitative data concerning the design outlines and some general characteristics concerning construction and system options. Based

Figure 2.3 Energy demand of a dwelling



Source: DGMR, 2004

on these input data and all pre-assumptions according to NEN 5128, the spreadsheet calculates (an indication of) the yearly energy demand. (It also estimates the construction costs of the involved building elements. However, due to lack of specifications, the usefulness of these construction cost data is rather limited.)

Just like Green-Calc does concerning environmental impact, this spreadsheet compares the resulting energy demand to the demand of a reference building in the same category and based on the same functional and formal design (see Figure 2.3). The disadvantages of that approach have been discussed in Section 2.5.5.

However, there is not any (scientific) problem to combine the energy demand estimating facility of the DGMR spreadsheet with the EVR assessment approach. According to Section 2.6.1, it is easy to connect eco-costs to energy demand, which is expressed in MJ. In Chapter 3 will be discussed how to determine the concept of value in the EVR related to energy demand.

2.6.6 Maintenance

Cleaning, servicing, maintenance and refurbishment work are necessary to maintain the usefulness of a building during its lifetime. LCA concerning these aspects needs assumptions (scenarios) regarding the useful lifetime of the building and the lifetime of the individual components (Lützkendorf, 2002). The actual values of the parameters, which are used in the scenarios, may substantially influence the outcome of the estimated environmental impact.

As noted in Section 2.6.3, renovation and refurbishment are considered to be activities belonging to the production phase of the life cycle of housing.

After renovation or refurbishment, the dwelling as a whole differs from the entity before those interventions, as to its principal functioning and value. Consequently, it can be considered to be a new product. Maintenance, on the other hand, comprises 'the technical and related administrative activities aimed at maintaining, recovering or approaching the initial or – in respect of the possibilities for use – comparable state of an object' (Hoenderdos and Priemus, 1985; Straub, 2001). Servicing can be considered as a form of maintenance, specialised for (mechanical, electrical and transportation) systems. So, as for functioning and value, a dwelling does not change but in degree, because of applied maintenance and servicing.

In the housing sector (in the Netherlands) maintenance mainly concerns the elements of the building's skin (exterior walls, windows, roofs) and (mechanical, electrical and transportation) systems. The various technical solutions for the elements may differ for their maintenance needs. Compare for instance a wooden window frame to a plastic one, or a brickwork elevation to a painted plaster finished façade.

In recent years in the Netherlands, maintenance has enjoyed relatively much attention (Straub, 2001). Several management models for maintenance have been developed (Damen, 1994 and 1996). However, in the (early) design stages, elaborated estimating of maintenance efforts is very unusual. As far as maintenance-costs are considered in these stages, design decisions are based on general knowledge (either from experience or sometimes from specialised studies on the subject).

At the Faculty of Architecture of Delft University of Technology, a maintenance calculating model has been developed for educational purposes. This tool has been elaborated for investigating the impacts of design decisions on the maintenance costs of residential buildings. What happens, for instance, if a different arrangement is chosen for a façade or if a different material is applied for roofing? What are the (financial) consequences of a different paint system?

The maintenance calculating model has been attached to the elements classification according NEN 2634 (NEN, 1999) and shows for clarity reasons a radically simplified approach of the various maintenance cycles. It calculates maintenance costs for several elements based on unit prices for pre-assumed activities, which are related and adjusted to various technical solutions for the involved elements. For wooden window frames e.g. a painting scheme is assumed and for plastic windows a cleaning sequence. Because of its basic structure and its connection to the NEN 2634, the model may be suitable for application by (Dutch) architects in early design stages. A survey of this maintenance calculating model is presented in Appendix 4.

Since the model relates maintenance activities to building components, estimating eco-costs for maintenance can be achieved via the same approach as described in Section 2.6.3 for the production phase.

2.6.7 Management and administration

In the housing sector, management and administration costs are usually rather independent from the specific building design. For estimating the related eco-costs, these costs can be considered as mainly related to 'labour in offices'. The procedure for assessing environmental impact of these types of activities has been described in Section 2.6.2. As mentioned before, in Chapter 3 and 5 the comparison of the estimated eco-costs in all life cycle stages will be discussed.

2.6.8 Eco-costs of housing in the end-of-life phase

In particular for assessing the end-of-life related environmental impact, the long useful life of houses (and buildings in general) creates a problem. The energy, emissions and materials flow involved in the demolition, removal and disposal processes has to be predicted. The long lifetime of buildings makes such predictions inevitably approximate (Lützkendorf, 2002).

Apart from this time-related problem, which will be resumed in Chapter 3, the end-of-life approach in the EVR model is rather simple. Demolition and separation costs are all covered by traditional economic costing. The pollution prevention costs of these activities can be estimated without considerable problems. The eco-costs of recycling or upgrading are assigned to the new products emerging from these processes. So, all eco-costs in the end-of-life phase after 'separation' are related to the waste fraction that is not fit for upgrading or recycling. This fraction could be charged with the 'eco-costs of land fill' according to Section 2.6.1. All benefits from preferable treatments on the 'Delft order of preferences' would be designated to products or energy resulting from those treatments (Vogtländer, 2001).

2.7 Summary and conclusion

Almost 10 years after the Brundtland report (1987), in the Dutch construction industry, the National Sustainable Building Packages have been published (1996). Based on a qualitative approach of sustainability, recommendations concerning (materials application in) construction are presented. Meanwhile, a quantitative approach of the sustainability question is developed. The most systematic method in this field is the Life Cycle Assessment (LCA). However, a 'full' classical LCA is very complicated and in that way less suitable for practical application in decision-making processes as in housing construction and management. In order to communicate the results of LCA (and other ecological impact studies) to the stakeholders in (building) development projects, several models have been developed that provide single eco-indicators.

Demolition of apartments from the 1960s (photo Frank Wassenberg).

From a list (based on various references) containing approximately 30 models, only three models that are suitable for application in the West European region are concluded to provide a single indicator based on the LCA method: Eco-Quantum, Green-Calc and the EVR model.

In the context of sustainability of housing, the assessment of interventions in the stock is of primary importance. So, one of the first requirements for a decision support tool is that it should be suitable for comparing demolition, new construction and renovation. Out of the investigated models, only the EVR model meets this requirement by relating the environmental burden (the eco-costs) of a product to its value.

One of the central concepts of the EVR model is defining eco-costs as 'virtual' costs related to measures, which have to be taken to make (and recycle) a product 'in line with earth's carrying capacity'. In other words, eco-costs are the costs of technical measures to prevent pollution and resource depletion to a level, which is sufficient to make society sustainable.

In the model, the eco-costs are specified as the sum of the marginal prevention costs of depletion of materials, energy consumption, toxic emissions, environmental burden of labour and environmental burden of depreciation (use) of equipment, buildings etc.

Like all models based on LCA do, the EVR model includes the whole lifecycle of a product. For housing, this lifecycle is depicted in an input/output relations diagram that discerns materials and products from activities (Figure 2.2). Apart from the land use cycle, which is beyond the scope of this research, the model discerns three (main) stages in the lifecycle of houses: the production phase, the operating phase and the end-of-life phase.

In the production phase, which includes new construction, refurbishment and renovation, the environmental burden can be considered as consisting of the eco-costs of semi-finished products plus the eco-costs of the assembling activities (including all the additional works like preparation works, building site facilities and management).

Databases like IDEMAT, Eco-Invent and MARKAL provide data concerning emissions and depletion of materials related to a large number of products and production activities. Based on these data, eco-costs can be estimated for materials and products that are applied in (housing) construction.

Eco-costs established this way have been implemented in the materials database of an estimating system that is used to produce elemental bills of quantities for the construction costs of new construction and renovation projects. This way a tool is acquired for estimating eco-costs in the production phase of these kinds of projects.

In the operating phase of housing, especially energy consumption and maintenance are related to environmental burden. Assessing environmental burden in this phase is complicated due to the long useful life of buildings. This time-related aspect is resumed in the next chapter.

As concerning the production phase, concerning the operating phase of housing, eco-costs can be estimated using existing tools. The intended tools estimate the energy demand and the projected maintenance costs of dwellings, based on the characteristics of the affected design. Eco-costs, which are deduced from the above mentioned databases, are implemented in the results of these estimates.

Assessing environmental burden in the end-of-life phase is complicated again due to the long useful life of buildings. Apart from that, eco-costs in this phase can be deduced from a demolition estimate in a way similar to estimating eco-costs in the production phase.

All in all a conceptual model has been developed for estimating the eco-costs in the entire lifecycle of housing. Balancing eco-costs to the value of a dwelling and mutually weighing the eco-costs in the various stages of its lifecycle is dealt with in the chapters still to come.

3 The value of houses

In this chapter the value aspect of the EVR model is elaborated for use in the field of housing. It deals with the research question: 'What is a meaningful approach of the concept of 'value' in the context of relating environmental burden to (less or more) added value as a result of design decisions concerning interventions in the housing stock?' In other words, which concept of value can offer a yardstick to measure whether the estimated eco-costs related to a certain housing project are really 'worth while'?

3.1 Introduction

3.1.1 General introduction

The EVR model evaluates the amount of ecological burden related to a certain product, expressed in eco-costs, by comparing it to the value of that product:

EVR = Eco-costs/Value.

Whereas in the housing sector many different methods are applied for assessing value, the question arises which determination of value is meaningful in this context. In order to find an answer to this question, it has to be kept in mind that the model, in which the concept plays a role, is aimed at supporting decisions in design processes of housing development projects. Therefore, a useful concept has to relate the value of houses (residential buildings) to their characteristics.

Of equal importance is that houses and other buildings can be distinguished as products with long useful lives, which implicates that their value may be affected by long-term changes (either by internal changes, i.e. degradation over time, or by external changes, i.e. changes in society of attitude as to particular types or characteristics of houses).

Finally, it will be considered that, in housing development projects, at least three different parties are involved, for whom the affected houses may have different values:

- the producers of houses, being the real estate development companies or the construction industry.;
- the owners of houses, being the housing associations or other real estate companies putting the houses into operation;
- the residents, either tenants or owner-occupiers, who are the final consumers of the provided services.

3.1.2 Rented and owner-occupied houses

In several sections of this chapter, houses are referred to as rented houses. This is done while this approach offers an easy distinction between the capi-

The lemma 'Value' in several dictionaries

Oxford Compact Dictionary & Thesaurus (1997):
Value is "(1) worth, desirability, or qualities on which these depend, (2) worth as estimated, (3) amount for which thing can be exchanged in open market, (4) equivalent of thing, (5) something well worth money spent, or (6) ability of thing to serve a purpose or cause an effect; (7) (in plural) one's principles, priorities or standards, (8) duration of a (music) note, or (9) amount denoted by algebraic term."

Dutch Dictionary Van Dale, 13th revised edition (1999, translated):
Value is "the amount of significance of a thing as a possession, by quality, as a means to an end, by relation or by a combination of these or some of these factors."

Dutch Dictionary Wolters' Grote Koenen, 1st edition (1986, translated):
Value is "(1) significance in the economic interaction of people or (2) significance in moral, spiritual, psychological, social, religious and aesthetic relations of people."

Value, price and costs (Porter, 1985)

In the consumer market, the 'fair price' is defined as the highest price at which a consumer is prepared to buy a product and/or service. When the price of a product is higher than the fair price, the consumer considers the product as too expensive. When the price is lower than the fair price, the consumer considers a purchase as attractive. So, the fair price equals the value for the consumer.

The bottom-line for the sales price of a product within the business chain is formed by the costs that are related to the production. A sales price, which is lower than these costs, will prevent transactions, at least in the longer term. On the top end, the sales price is limited by the fact that it equals the costs for the buyer. If the asking price would exceed the potential buyer's budget, there would not be a transaction either. Apparently, the value of products, indicated by the effectuated sales prices in the business chain, is closely related to the production costs.

tal aspect and the consumer aspect of housing. A house can be considered to be a capital good effectuated by an investment. A housing service is a consumer good, produced by the house together with other production factors (Conijn, 1995 in accordance with Muth, 1960).

This study concerning the value of houses is not intended to be a further development of the economic theory of the market value. It is aimed at relating the value of a house to the residents' appraisal of the housing services. It is also aimed at exploring the development of both factors over time (related to the 'aging' of the house). The result of the study should offer an opportunity for reflection within the context as described in the previous section.

3.1.3 Introduction to the concept of value

In the EVR model, the value – the amount for which a product or service can be exchanged in an open market – is identified by the 'sales price' within the business chain and the 'fair price' in the consumer market.

For commodity goods, of which many items are sold and bought on a day-to-day basis, the value of products can be determined by observing sales prices. Some markets, however, for instance markets referring to capital goods or other utensils with long useful lives, show little transactions compared to the quantity of items which are potentially in the market. Real estate and housing markets belong to this category. On these markets, it is much less easy to establish the value of products by observing sales prices. Moreover, houses and other real estate objects are often 'unique' products, tailor-made in a given situation, linked to a specific site and practically not transportable (for use in another site). That makes it even more difficult to assess their value by comparing them to other buildings, which recently have been sold (Stahl, 1985).

3.2 Theoretical approach

3.2.1 Future profits

Starting from the general notion of 'value' (see the lemma 'Value' in several dictionaries), the value of an object can be described as the economic sacrifice, which someone is prepared to pay in order to get the benefit from possession of that object (A). The benefit from possession only starts at the moment, at which one can actually dispose of the object. This leads to the conclusion that the value of an object is determined by the capitalisation of the future benefits. All facts concerning the object, which have occurred prior to the acquisition of the object, are not relevant anymore for the value of the object. So, the object's original costs are not relevant. Neither are the amounts of discounting, nor a recent investment, nor the benefits the former owner has enjoyed from the object. It is quite possible that an object, which has been very expensive for the former owner, is not of any value whatsoever, because there is no one in the market, who can make the object useful one way or another (B).

A different certainty is that real estate objects are built for several purposes. Consequently, in these cases, the 'capitalised future benefits' cover the costs spent on the objects. As can be observed, in several categories of real estate, numerous objects are being constructed. So, apparently, the costs of these objects are equal to or less than the 'capitalised future benefits' for the affected owners. Conclusion: the cost price of a real estate object will be equal to or less than the present value of the (expected) net future profits from that object. Note that in practice, 'less' will not occur very often and for sure not to a high degree, because the seller surely would adapt his price to the possibilities he would suppose in respect of the buyer.

So, the present value of all net future profits is the primary starting-point for assessing the value of a real estate object (C). Note in this context, that savings have to be capitalised as profits, but that depreciations, not being cash-flows, should not be counted (Seijffert, 2003).

3.2.2 Replacement costs as the bottom-line of value

Secondary, an indirect method is applicable: assessing value by identifying this value as the cost price of a substitute object. This assessment method is called the corrected replacement value (D). Actually, such a calculation refers to a virtual situation; therefore it should be applied carefully and discretely. The method is not usable for the appraisal of very old buildings, for monumental buildings, for buildings at a specific location and for buildings with considerable deviations from the general characteristics of the buildings in their category (Seijffert, 2003).

Though the first description of the concept of value (according to A) can hardly be denied, the practical elaboration (according to C), in which the value of a real estate object is determined as the present value of the net future profits from the object, is not without problems.

How much will these net future profits be? (The following example concerns dwellings, but the conclusions are applicable for other buildings too.) The rent of a certain house is, for instance, €500 a month. The value of this house could be calculated by means of the discounted cash-flow method based on this amount (and other required parameters). Suppose the calculation results in a value of €200,000. Now, four other proprietors decide to build another 100 of these dwellings, which appear to have building costs of €175,000 each. At a rent level of €500, in the market (in this particular region) effective demand for this type of dwellings only amounts to a maximum of 75 houses. So, it is just a matter of time, before one of the proprietors will decide to offer his houses for a monthly rent of €450.

This being the case, also the value of the other dwellings will diminish. In time; tenants will not be prepared to pay the 'sacrifice' of €500 a month for a housing service, which they can obtain for €450 elsewhere nearby. So, by this fact the value of this particular housing service is set on €450 a month and the value of the houses will equal the corresponding net present value, say €180,000. Depending on the rise in demand at the lower rent level for these particular dwellings, the process will result in a new balance. Finally, the replacement value (according to D) – in this example €175,000 – will be the bottom-line of this kind of movements. Clearly, a proprietor, who has to invest more than the value of his dwellings, being their 'capitalised future benefits' (according to C) will not last very long in terms of economic life. However, if the replacement costs exceed the maximum amount, which the intended tenants are able to spend, the costs will not reflect the value (according to B). Apparently, the market for this particular type of dwellings will reach saturation and the dwellings will not be on offer anymore.

In a perfect market, the value of the houses will finally be determined by the (all-in) construction costs of comparable new houses (the replacement value) plus a small margin:

Value = costs + profit + taxes.

(Note that the 'profit' in this equation is a different one than the 'future benefits' or 'net future profits' as mentioned above (according to A and C). The 'profit' in the equation is the profit for the seller of the 'comparable new house', while the 'profits' as mentioned above are the profits for the buyer of the house, in the capacity of operating proprietor.)

3.2.3 Value as related to building characteristics and their development in time

Designing new (types of) dwellings however, architects attempt to identify, how the highest value can be obtained at the lowest costs. This design process is – by its nature – directed to the physical characteristics of houses, such as floor area, number and size of rooms, number of stories etc. Also types of construction and used materials are subject to this design process.

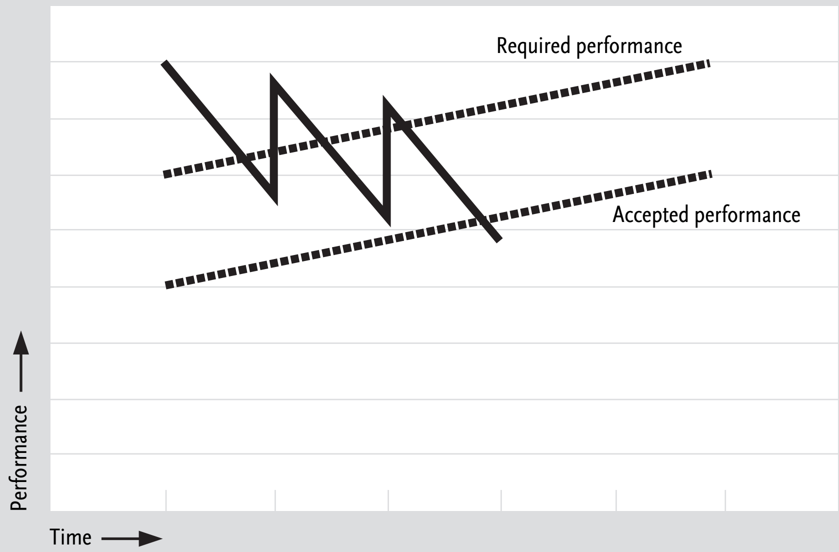
In this process, the information that, generally spoken, (in a perfect market) the value of houses is determined by the all-in construction costs, is not of any use. Of course, the value of the product cannot be expected to rise just because the architect is substantially increasing the production costs.

However, if architects succeed in designing houses with higher value (in the sense of more desirable characteristics) at the same amount of costs, before long the new relation between characteristics and cost level would become the starting point for assessing the value. Consequently, the value of earlier built houses would diminish. While actually innovations in the building industry induce these kinds of improvement of building characteristics all the time (albeit in small steps), indeed the value of existing houses tends to decrease, even if the performances of existing houses keep the same level.

Of course, also in this respect, not all changes turn out to be improvements. In the years between 1970 and 2000, the majority of houses in the Netherlands was built with a clear height of the rooms, not exceeding 2.50 m. Building at lower heights, compared to the previous years, was partly done to save on building costs for 'not needed height' and partly to keep heating costs low. Both aspects seemed to be desirable characteristics of dwellings at the time. Nowadays, many people find this low ceiling height unpleasant, which may reduce the value of the houses from that period.

Anyway, people are hardly aware of the effect of innovations on the value

Figure 3.1 Loss of performance and maintanance of buildings



Source: Vroman, 1982

of houses. The value of money (in terms of purchasing power) is usually decreasing even faster than the value of the houses. These alterations in the purchasing power of money, as such, form a problem for assessing value anyway (Seijffert, 2002). Another fluctuation – probably more substantial – of the value of houses over time is effectuated by the gradual loss of performances due to wear and tear and the periodical recovery of performances by means of maintenance activities (Vroman, 1982).

3.2.4 Residential location

An important factor for the value of houses is the so-called residential location. In a broad sense, the theories of residential locations fall into two main groups: the market approach and the non-market approach. The most developed theory of residential location within the market approach is the theory of the travel-cost/housing-cost trade-off (also called access/space trade-off). The non-market approach tends to criticise the market based theories that are characterised by their unhistorical outlook. It points out that instead of resulting from market competition, land and house price – and by extension, residential location patterns – are strongly influenced by landed capital through monopolistic rent (Phe and Wakely, 2000).

Phe and Wakely remark that both market and non-market approaches have shown considerable discrepancies when applied to real-life situations. Among the phenomena that could not be explained, gentrification is a very telling example. Phe and Wakely present a theory for the dynamics of urban residential areas, which overcomes these discrepancies. It is the theory of the housing status/dwelling quality relationship. In this theory, housing status is

Urban residential location theory (by Phe and Wakely)

Residential areas in cities make up largely continuous and overlapping rings around the status pole or poles. The ring pattern is the outcome of a trade-off between desirable status and acceptable level of dwelling quality.

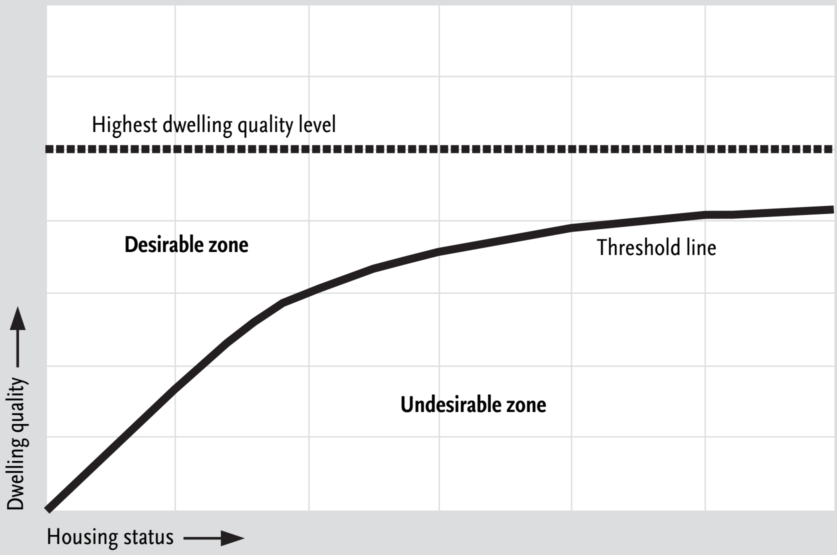
House value for any social group consists of two components: housing status (HS) and dwelling quality (DQ). Housing status is a combination of attributes, often non-physical, that distinguish different levels of housing desirability, or status, which are accepted by certain social groups, sometimes irrespective of the actual physical state of the dwelling. Dwelling quality embodies the physical, measurable elements that constitute the basis for the normal use of the dwelling.

At any level of housing status, there exists an acceptable level of dwelling quality, or point, below which houses are considered as sub-standard. The locus of these points forms a line called the dwelling quality threshold (Figure 3.2).

This threshold divides the whole housing stock in question into two zones:

- The zone above the threshold is called 'desirable'; the zone below it is called 'undesirable'. Each housing situation (of a country or city) has a uniquely characteristic quality threshold that can be compared with others.
- At the lower price levels, dwelling quality is the dominating component, while at the higher price levels, housing status predominates. With a certain degree of simplification, it can be said that housing units at the lower price levels are mainly characterised by their utility as shelter – i.e. by their use value, while houses at the higher price levels are characterised more by the attributes that make them commodities and favourable investments – i.e. by their exchange value.

Figure 3.2 Housing status and dwelling quality



Source: Phe and Wakely, 2000

a measure of the social desirability attached to housing in a particular locality. It can represent wealth, culture, religion, environmental quality etc., dependent on the current value system of a given society and, as such, it is

Apartments in Oudenbosch (new construction).

closely related to concrete historical conditions. Dwelling quality in this theory includes the physical, measurable characteristics as referred to in the previous section and as given by Garvin (and described in Section 3.4.1).

In the theory of the housing status/dwelling quality relationship, the dynamics of change in the residential areas of cities, and, by extension, the value of land and houses are conceptualised as consisting of a simultaneous shift along these two dimensions. Instead of being the results of the economic access/space trade-off, the patterns of residential location in cities have been shown (in a case study concerning Hanoi) to be the outcome of other kinds of trade-off, which are largely social in nature – the ones that are based on status and the social acceptability of dwelling quality (Phe and Wakely, 2000).

3.2.5 Value as related to other factors

Apart from factors related to building characteristics, all kinds of other factors influence the value (price) of a house and its development: the shortage of housing in general or the shortage of a certain type of housing, regulating government interferences like grants and taxes, general economic factors like the development of purchasing power or the (dynamics in the) level of interest rates (e.g. Boelhouwer and de Vries, 2004). While these factors may be of major importance to the amounts of money, which are spent on building or renovating houses in general, they are not expected to have a specific influence on design alternatives in particular projects. Therefore, these factors are not included in the research.

3.2.6 Summary

The presented theoretical exposition can be summarised in the following statements, which are valid simultaneously:

- Value of houses is determined by (discounted cash flow of) future profits.
- Value of houses is related to the (actual) all-in building costs of houses.
- Value of houses is related to desirable characteristics/performance.
- Value of houses is gradually diminishing due to innovations.
- Value of houses is fluctuating by a combination of maintenance and loss of performance.
- Value of houses is related to their location in the context of trade-offs based on status and the social acceptability of dwelling quality.
- Value of houses is influenced by housing market factors (e.g. general shortage of housing) and other economic factors (e.g. interest levels).

3.3 Assessing value

3.3.1 Value assessment approaches in practice

In the context of housing and real estate appraisal, several approaches have been developed for assessing the value of objects. The need for these approaches has evolved from the desire to cope with the imperfections of the real estate market, being non-transparency, immobility, delay of price-reactions, lack of consumers' sovereignty and existence of emotional ties (Priemus, 1978). In the Netherlands, the following approaches can be discerned (Ten Have, 1997):

- The comparative approach – Assessment by comparing recently effectuated transactions in the market to the object under valuation.
- The cost approach – Assessment based on construction costs plus land costs, if necessary corrected for depreciation.
- The income approach – Assessment based on the capitalisation of future profits.
- The legal approach – Assessment based on legally prescribed valuation methods.

The first three assessment approaches can easily be related to the theoretical exposition in the Section 3.1 and 3.2. The legal approach can be considered as a series of elaborations of value assessment for cases in which government wants to keep control. Appraisal prescriptions in the Dutch Residential Tenancies (Rent) Act 1979 ('Huurprijzenwet Woonruimte 1979') and the Valuation of Immovable Property Act ('Wet Waardering Onroerende Zaken') are examples of this last approach.

In principle, all approaches of value assessment can be used in the context of the EVR model for housing. The discerned approaches are effectuated by using various methods (Ten Have 1997). An exposition of all these methods is beyond the scope of this study.

Conservatory houses at Roosendaal (new construction).

3.3.2 Various definitions of value

Accountants, real estate appraisers and quantity surveyors apply various concepts of value. Which concept they use in a specific case, depends on the aspect of value that is to be accentuated by the valuation results in order to be useful in the specific situation.

Accountancy based elaborations, used in the field of social housing in the Netherlands, are: historical cost value, replacement value, direct yield value and indirect yield value (or going-concern value). For the historical cost value there is just one practical application: it can serve as a basis for calculating the amount to which properties are included in the proprietor's accounting records (Bouma, 1980 in Gruis, 2001), no more and no less. The other three concepts are aimed at describing the actual value of the object from different viewpoints.

Dutch real estate appraisal involved with the private part of the housing sector, uses – for the market of commercially let properties or owner occupied houses – the concepts of: private market-value free from rent or use, private market-value as let(table) object, execution value free from rent or use, execution value as owner occupied and execution value as let(table)object (Ten Have, 1997; Gruis, 2001; Conijn, 2002 and CFV, 2003). All concepts in this group are aimed at describing value based on the actual situation, presuming different conditions in that situation.

In the United Kingdom, accountants and quantity surveyors use concepts like existing use value, open market value, estimated realisation price, estimated restricted realisation price, going-concern value and depreciated replacement cost value (Ten Have, 1997; Eccles et al., 2000). In Germany, comparable concepts can be found, like 'Zeitwert', 'Verkehrswert', 'Gemeiner Wert', 'Betriebswert', 'Wiederbeschaffungswert', 'Wiederbeschaffungszeitwert'.

In general, the concepts used in different countries in Western Europe and in the United States of America show great resemblance (Ten Have, 1997). However, the definitions of the British concepts are slightly different from e.g. the Dutch or the German ones. These definitions, in their turn, may differ on various aspects of their elaborations from definitions in Belgium, France, Canada, USA, Australia etc. Referring to the confusion and disagreement caused by the varying 'verbal value definitions' used all over the world, a study in Perth Australia suggests a statistical definition of value, which has four clauses (Kummerow, 2002):

- Estimates of parameters of the subject property's sale price distribution.
- Estimates of errors in the parameter estimates and diagnostic tests.
- Forecasts of the stability of the estimates over a relevant period.
- Statements of explicit assumptions about specified circumstances of sale.

Practically, this definition expresses the value in terms of the statistical operations, which are executed in a correct valuation procedure anyway. (Ten Have e.g. describes comparable operations as parts of valuation theory.) The advantage of this approach may be more clarity for experts, the disadvantage is obviously that clients would need more skills to understand the meaning of value that is expressed in such terms.

3.3.3 Applicability in the context of EVR

For assessing the value of houses as objects for market transactions immediately after completion of construction activities, in principle all approaches and definitions (except the historical cost value) can be used. In other words, for purposes of sustainability optimisations in housing development projects, all approaches and definitions are applicable as far as the production phase is concerned. However, in order to compare the EVR of different houses, the value of the houses should be assessed according to the same methods and definitions.

Sustainability optimisations concerning the operating phase need further consideration. All of the above mentioned approaches for assessing value are mainly aimed at providing financial data in the context of purchase, finance or commercial feasibility calculations. Consequently, the approaches do refer to potential future profits or to building costs in one way or another, but they give little attention to relations between the value and the less or more desirable characteristics of houses. Especially, knowledge about these very relations is important for architects (and other stakeholders) in the design process.

3.4 Managing value

3.4.1 Value and quality dimensions

In the classical economic approach, the relation between the value of a building, its characteristics and its cost price seems a simple one: high value is effectuated by high quality which is obtained by application of the best materials and skills providing the best building characteristics. Of course this combination would also entail the highest costs.

In the 1970s and 1980s (American) industry has experienced, that the relation between value, quality and costs was not that simple. In his study 'Managing quality', Garvin explains, that there are several dimensions of quality, which all have their own specific relation to value and costs (Garvin, 1988). For industrial products he discerns 10 quality dimensions: performance, features, conformance, durability, reliability, serviceability, customer care, aesthetics and reputation.

For reasons of practical applicability in a decision support tool for product optimising, Vogtländer has clustered these 10 dimensions of quality in three major aspects: product quality, service quality and image (Vogtländer, 2001). For complex products like houses, a further subdivision of quality dimensions seems to be of more practical value than a clustering. Table 3.1 shows an elaboration in this respect.

Essential for the quality dimensions is that they are determined by product characteristics 'as perceived by the customers' (Garvin, 1988). So, quality can only be judged by customers. In the case of houses, the final judgement of their quality should be expressed by the residents (being tenants or owner-occupiers). In the Netherlands several attempts have been made to compose tools for assessing residents' preferences (Vroegop and Giele, 1986; Van der Werf, Lans, Stikvoort and Thomsen, 1989). These 'quality assessment tools' consist of numerous questions referring to very detailed analyses of possible quality aspects of houses.

The proposed tools show considerable problems in respect of their operational application on a broader scale, which are related to the rating of quality and the weighting of the various quality aspects (Lans, 1996).

A more fundamental problem of the 'quality assessment tools' is that fixed valuation criteria have been assigned to the majority of the quality aspects. ("A dining area should have at least 8.5 m^2 usable area, a bedroom should have a window… etc.") Tools composed in this way do not necessarily reflect product characteristics 'as perceived by customers'. So, their applicability for value assessment purposes is limited.

3.4.2 Value and building characteristics

Garvin's quality dimensions are purely intended to specify the quality of a product as a whole. Houses, however, are complex products which fulfil various functions. Therefore, it is not easy to judge e.g. the quality dimension performance of a house at one go. So, some of the descriptions of quality dimensions as elaborated in Table 3.1, draw the attention to specific parts of the building, where apparently these dimensions are concentrated. For instance, a dimension of the product quality of houses, which is related to performance as well as conformance and durability, is referred to as fitting and finishing. In houses, several building parts can be discerned, which are attached to various specific functions and therefore may require different characteristics as for fitting and finishing. Kitchens and bathrooms e.g. fulfil specified functions which require special equipment and (water proof) finishing. Especially because of the restricted functions of such building parts, customers are likely to experience them as specific units within a house, to which an overall judgement can be attached. ("This kitchen is very functional for preparing meals, but too small for our family to sit and have lunch in; so it is given 6 out of 10 points.") Also building parts like heating systems, ventilation and electrical systems can be considered being referred to by customers in this way. Note that Table 3.1 does not show criteria for valuation; it only discerns various dimensions of value and various parts of the building.

3.4.3 Customer quality valuation

As concluded in Section 3.4.1, a problem of subdividing the discerned quality dimensions into more detailed sub-dimensions is the increasing amount of (explicitly or implicitly) presumed criteria, which have to be validated through (more) research concerning residents' preferences. If in a valuation model, subdivisions of quality dimensions are made in too much detail, these dimensions will not correspond to clear customers' quality perceptions any more. Such a model will consequently lose its applicability as a tool to identify (and quantify) the attribution of the discerned quality dimensions to the value of the product. This conclusion indicates the need for a limitation to the extent, in which quality aspects should be specified (for this purpose).

In sectors other than housing, the 'Customer Value model of Gale' is used to quantify the value of a product-service system in order to be able to analyse the competitiveness of a product portfolio of a company (Gale, 1994). Applied to a situation in the market for rented houses, this model could produce a survey as shown in Table 3.2 (see page 60).

Table 3.1 Quality dimensions of houses

Dimensions (Garvin, 1988)	Exemplary elaborations of quality dimensions of houses	
Product Quality		
Performance	**1. Size and lay-out**	
	a. size as related to function	Is the apartment or house big enough for the number of residents?
	b. lay-out as related to function	Do rooms have right sizes, relations etc.? Distribution of space over separate rooms e.g. the number of bedrooms, how many large ones and how many small ones. Living room: the size of the living room and its relation to other rooms e.g. open-plan kitchen or French windows to terrace.
Conformance durability	**2. Structure**	
	a. structural quality	Does the building make a stable and sturdy impression?
	b. sound insulation	Quality of sound insulation related to either neighbours or traffic noise.
	c. thermal insulation	Quality of thermal insulation of the facades, (ground) floors and roofs.
	3. Type	
	apartment	Territory aspects within the block (dwelling, block, street, view, individuality, privacy, nuisance or help from neighbours).
	a. main entrance, accessibility	What is quality of main entrance?
	b. lift	Is apartment accessible by lift?
	c. balcony/roof terrace	What is quality of balcony/roof terrace?
	single family house	Territory aspects of the dwelling (presentation, individuality, privacy).
	a. entrance, accessibility	What is quality of main entrance?
	b. mi	pm
	c. garden	What is quality of garden, if any?
	extra	
	d. garage/storage	What is quality of garage, if any? Storage (shed, garage, carport, basement car park).
Reliability	**4. Fitting and finishing**	
	a. kitchen	Quality of kitchen equipment.
	b. bath/toilet	Quality of toilet and bathroom fittings.
	c. heating	Quality of heating system.
	d. ventilation	Quality of ventilation system.
	e. electrical system	Quality of electrical system.
	f. finishing	Quality of finishing: floor finish (parquet floor, tiled floor etc.), wall finish (fine rendering, tiled wall etc.), ceilings (plasterboard, fine rendering, system).

The technique is that the customer (tenant) is asked to estimate the value of the house in which he/she is living, in terms of the fair price for it (as described in Section 3.1). In the table this fair price is expressed as a monthly rent. Next, the tenant is asked to rate the various quality dimensions (by report-marks; in the Netherlands, report-marks are ranging from 1, very poor,

Dimensions (Garvin, 1988)	Exemplary elaborations of quality dimensions of houses		
Service Quality			
Serviceability	**1. Maintenance**		
		a. maintenance (condition)	Existence (or absence) of maintenance defects. Maintenance in design (the building, as designed, needs little maintenance the required maintenance can be carried out quickly and easily) and planned maintenance (is it done systematically and at a sufficient quality level).
Customer care	**2. Customer care**		
		a. service	Accuracy (are complaints, e.g. concerning central heating defects, addressed quickly and effectively). Customer service in case of a breakdown (e.g. heating).
Features	**3. Options**		
		a. options	Optional services (e.g. solar heater) or options concerning provisions (alarm system, holiday surveillance, cleaning).
Image			
Aesthetics	**1. Dwelling/block**		
		a. image of building	External appearance of building (impressive/modest, closed/open, severe/fanciful, classical/modern).
Reputation	**2. Surroundings**		
		a. neighbourhood	Quality of neighbourhood. Direct surroundings as experienced (street, view, traffic, privacy, contacts). Location of the dwelling in the neighbourhood, town (neighbourhood characteristics: quiet/busy, urban/rural, facilities, culture, nature).
	3. Reputation		
		a. reputation	Reputation of building block, landlord, etc.

to 10, excellent). Of course the tenant is informed about the meaning of the discerned quality dimensions, for instance in terms of the examples in Table 3.1. Finally the tenant is asked to indicate the importance (to him/her) of the quality dimensions. Here, the total amount should be 100% for all quality dimensions together. Based on the figures, which have been indicated by the

Table 3.2 Quality dimensions of houses: assigning value to dimensions

Clusters in EVR	Exemplary elaborations of quality dimensions of houses..									
	Q dimensions	Weighting (%)		Q rating		Weighed Q		Value (€)		
1 Product Q	1.1 Size and lay-out	15		5		0.8		64	48	
	1.2 Structure	25		4		1.0		64	64	
	1.3 Type	10	56	4	4.3	0.4	2.4	64	26	154
	1.4 Fitting and finishing	6		4		0.2		64	15	
2 Service Q	2.1 Maintenance	1		8		0.1		64	5	
	2.2 Customer care	7	11	7	6.3	0.5	0.7	64	32	44
	2.3 Options	3		4		0.1		64	8	
3 Image	3.1 Dwelling/block	10		6		0.6		64	39	
	3.2 Surroundings	20	33	4	4.8	0.8	1.6	64	52	102
	3.3 Reputation	3		6		0.2		64	12	
		100				**4.7**	**4.7**	**64**	**300**	**300**

Source: Gale, 1994 (in: Vogtländer, 2001)

tenant, now the fair price for the discerned quality dimensions can be determined by calculating the weighed averages of the ratings and assigning the corresponding portions of the total fair price to the quality dimensions.

Application of this approach offers two options to achieve a high 'relative quality', being a high quality at the right price:

- the company can either improve the quality/price ratio of the quality dimensions which are important to the customers
- or try to influence the customers' preferences in the direction of those quality dimensions of the company's products which are relatively high in comparison with the competitors.

3.4.4 Need for further research

In a few experimental assessments, which have been executed to explore this approach, the interviewed tenants tried to make trade-offs between several quality aspects, when they discovered that the importance of the dimensions they indicated, threatened to exceed the 'available 100%'. In some cases they would also readjust quality ratings in accordance with the revised weighting figures, until they were satisfied with the overall picture. This behaviour indicates that the interviewed persons were able to understand the model and to use it autonomously to express their own perception of the value of the affected dwellings.

The interviewed tenants were well-educated young people. Further research will be needed to test the operational applicability of this approach in the field of housing on a broader scale. Further research is also needed to investigate the relation between this customer value approach according to the model of Gale and the approach according to the housing status/dwelling quality relationship by Phe and Wakely (as described in Section 3.2.4).

In this study, however, the approach is only used as an experiment of thought (in Section 3.5).

'Woningwaarderingsstelsel' (Housing evaluation system), MVROM, 2003

The so-called 'Woningwaarderingsstelsel' (WWS), the housing evaluation system, which is used in commission of the Dutch Ministry of Housing, Spatial Planning and the Environment to establish the maximum reasonable rent level for a dwelling, based on precisely defined characteristics, is not considered to be a value assessment model in the context of this study. The WWS is not assessing value that is related to the fair price and/or quality dimensions 'as perceived by the customers'. Instead it determines 'value', based on standardised requirements.

3.5 Value development in housing

3.5.1 Layers of change

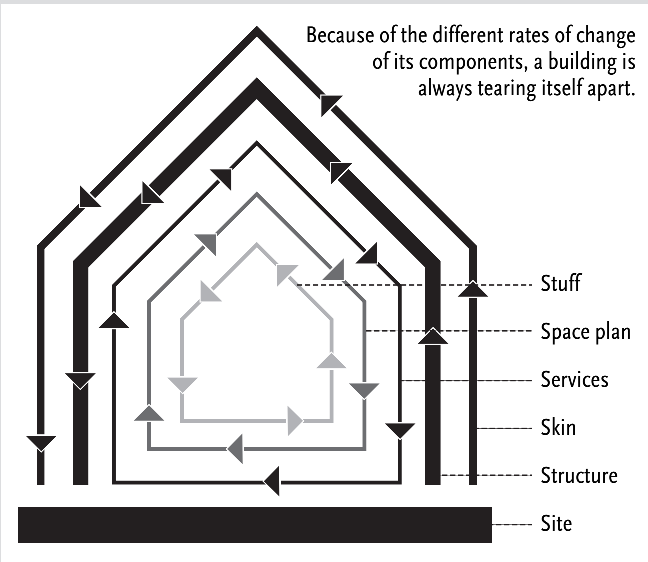
As concluded in Section 3.2.3 value and quality of houses tend to fluctuate over time. And as houses usually have a long useful life, this time-aspect should be involved in the research.

A study, that relates the changes of a building to its structural composition, is the model of the 'shearing layers of change' (see Figure 3.3) (Brand, 1994). This model discerns six layers in a building, of which each shows a particular life cycle with a particular length of its useful life.

Definitions and examples of the six S-layers are directly quoted (Brand, 1994):

- Site – This is the geographical setting, the urban location, and the legally defined lot, whose boundaries and context outlast generations of ephemeral buildings (…).
- Structure – The foundations and load-bearing elements are perilous and expensive to change, so people don't. These are the building. Structural life ranges from 30 to 300 years (but few buildings make it past 60, for other reasons).
- Skin – Exterior surfaces now change every 20 years or so, to keep up with fashion or technology, or for wholesale repair. Recent focus on energy costs has led to re-engineered skins that are air-tight and better-insulated.
- Services – These are the working guts of a building:

Figure 3.3 Shearing layers of change



Source: Stewart Brand, 1994

Table 3.3 Customer value model of Gale for a newly built 73 m² apartment

UFA (NEN 2580) 73 m²	Importance score		Q rating	Weighed score		Fair price	
P r o d u c t Q u a l i t y							
Size and lay-out							
1. size as related to function	9.5%		8.0	0.80		68	
2. lay-out as related to function	5.2%		8.0	0.40		37	
		15%			1.2		105
Structure							
3. structural quality	2.4%		8.0	0.20		17	
4. sound insulation	16.4%		8.0	1.30		117	
5. thermal insulation	6.2%		9.0	0.60		50	
		25%			2.1		183
Type							
Apartment							
6. main entrance. accessability	1.0%		8.0	0.10		7	
7. lift	7.2%		9.0	0.60		57	
8. balcony/roof terrace	1.4%		6.0	0.10		8	
Single family house							
6. entrance. accessibility	-	0.0%	-	-		-	
7. mi	-	0.0%	-	-		-	
8. garden	-	0.0%	-	-		-	
extra							
9. garage	-	0.0%	-	-		-	
	-	10%			0.8		72
Fitting and finishing							
10. kitchen	1.9%		8.0	0.20		14	
11. bath/toilet	1.9%		8.0	0.20		14	
12. heating	1.9%		9.0	0.10		15	
13. ventilation	1.4%		8.0	0.10		10	
14. electrical system	1.4%		8.0	0.10		10	
15. finishing	6.7%		7.0	0.50		42	
		15%			1.2		104
		65%			**5.2**		**464**

communications wiring, electrical wiring, plumbing, sprinkler system, HVAC (heating, ventilating and air conditioning), and moving parts like elevators and escalators. They wear out or obsolesce every 7 to 15 years. Many buildings are demolished early if their outdated systems are too deeply embedded to replace easily.

- Space plan – The interior lay-out – where walls, ceilings, floors and doors go. Turbulent commercial space can change every three years or so; exceptionally quiet homes might wait 30 years.
- Stuff – Chairs, desks, phones, pictures; kitchen appliances, lamps, hair brushes; all the things that twitch around daily to monthly. Furniture is called *mobilia* in Italian for good reason.

UFA (NEN 2580) 73 m²	Importance score		Q rating	Weighed score		Fair price	
S e r v i c e Q u a l i t y							
Maintenance							
16. maintenance (condition)	7.2%		9.0	0.60		57	
		7%			0.6		57
Customer care							
17. service	1.9%		8.0	0.20		14	
		2%			0.2		14
Options							
18. options	3.9%		7.0	0.30		24	
		4%			0.3		24
		13%			**1.1**		**95**
I m a g e							
Dwelling/block							
19. image building	4.3%		8.0	0.30		30	
		4%			0.3		30
Surroundings							
20. neighbourhood	14.3%		8.0	1.10		102	
		14%			1.1		102
Reputation							
21. reputation	3.8%		8.0	0.30		27	
		4%			0.3		27
		22%			**1.8**		**159**
		100%			**8.1**		**718**

The terms of useful life of the discerned ‘layers’, as indicated by Brand, do not differ much from observations in Dutch housing and renovation practice. Based on Thomsen (Thomsen, 2002) and based on self-acquired practical experience, assumed renewal of ‘services’ every 15 years and of ‘skin’ and ‘space plan’ every 30 years is quite likely, while for the ‘structure’ of houses in the Netherlands (and Europe in general), an average lifespan counting over 300 years is inevitable. (The capacity of the construction industry only allows replacement of 0.2% of the housing stock per annum.) An important ‘drive’ for renovation activities is also the continuously increasing demand for floor space per person (Thomsen, 2002).

Table 3.4 Customer value model of Gale for the same 73 m² apartment (quality and value in 30 years time)

UFA (NEN 2580) 73 m²	Importance score		Q rating	Weighed score		Fair price	
Product Quality							
Size and lay-out							
1. size as related to function	9.5%		6.0	0.60		51	
2. lay-out as related to function	5.2%		4.0	0.20		19	
		15%			0.8		69
Structure							
3. structural quality	2.0%		7.6	0.20		14	
4. sound insulation	16.4%		4.0	0.70		58	
5. thermal insulation	6.2%		4.5	0.30		25	
		25%			1.1		97
Type							
Apartment							
6. main entrance. accessability	1.0%		4.0	-		3	
7. lift	7.2%		4.5	0.30		29	
8. balcony/roof terrace	1.4%		3.0	-		4	
Single family house							
6. entrance. accessibility	-		-	-		-	
7. mi	-		-	-		-	
8. garden	-		-	-		-	
extra							
9. garage	-		-	-		-	
		10%			0.4		36
Fitting and finishing							
10. kitchen	1.9%		4.0	0.10		7	
11. bath/toilet	1.9%		4.0	0.10		7	
12. heating	1.9%		4.5	0.10		8	
13. ventilation	1.4%		4.0	0.10		5	
14. electrical system	1.4%		4.0	0.10		5	
15. finishing	6.7%		3.5	0.20		21	
		15%			0.6		52
		64%			**2.9**		**254**

3.5.2 Housing quality and time

It is reasonable to assume that people do not want to continue living in houses they judge as being insufficient; at least if they can make a choice. If a landlord is reluctant to improve his houses, tenants often make improvements at their own expenses, unless they have other options, like moving to (affordable) houses that provide better living conditions.

Suppose, in a 30-year-old house, refurbishment has been planned, consisting of renewal of the 'services', the 'skin' and the 'space plan' as described in Section 3.5.1. At the moment right before the refurbishment, the tenants'

UFA (NEN 2580) 73 m²	Importance score			Q rating	Weighed score			Fair price		
S e r v i c e Q u a l i t y										
Maintenance										
16. maintenance (condition)	7.2%			6.8	0.50			43		
		7%				0.5			43	
Customer care										
17. service	1.9%			4.0	0.10			7		
		2%				0.1			7	
Options										
18. options	3.9%			3.5	0.10			12		
		4%				0.1			12	
			13%				**0.7**			**62**
I m a g e										
Dwelling/block										
19. image building	4.3%			4.0	0.20			15		
	4%					0.2			15	
Surroundings										
20. neighbourhood	14.3%			8.0	1.10			102		
		14%				1.1			102	
Reputation										
21. reputation	3.8%			8.0	0.30			27		
		4%				0.3			27	
			22%				**1.6**			**144**
			100%				**5.2**			**460**

The assumptions concerning the value development are based on Brand's indications referring to the renewal of 'services' (quality dimensions 7, 10, 11, 12, 13, 14, 17, 18), 'space plan' (dimensions 2, 9, 15), 'skin' (dimensions 4, 5, 6, 8-balcony, 19) and 'site' (dimensions 8-garden, 20, 21) and on Thomsen's remarks referring to the development of the amount of living area used per person (quality dimension 1) and to the replacement capacity of the construction industry (dimension 3).
The value development of dimension 16 is 50/50 based on Brand's 'services' and 'skin'.
In accordance with the discussion above, the quality rates for dimensions related to 'space plan', 'skin' and 'services' are reduced with 50%. The rating for the 'site' related quality dimensions remains unchanged, and quality rates for dimensions 1 and 3 are reduced with 25% and 5% respectively.

appraisal of the building parts, which are to be renewed, does not equal 'zero'. Probably the value rates of the affected building parts equal 5 or 4 points (out of 10), which is approximately 50% of the valuation of comparable new building parts. If the valuation had been higher, refurbishment would not have been rational. If the valuation had been lower, tenants probably would have moved or they would have made improvements at their own expenses in earlier days.

According to the 'customer value model of Gale', the (affected part of the) fair price is in proportion to the weighed quality rating as given by the tenant. Table 3.3 shows in an imaginary case, the assumed distribution of importance and rating of quality dimensions for a newly built apartment. The rating affirms, what can be expected for new, well-designed apartments.

The total fair price represents a monthly rent, which is considered to be reasonable for a new apartment in this category. Note, however, that the general price level of the (total) rent is neither determined by the quality rating, nor by the importance score. So, the model of Gale does not explain the general price level of (a certain type of) houses, it just clarifies the relation between what is perceived by the customer as a *fair price* and the various quality dimensions. Table 3.4 shows the scores that can be expected for the same apartment after an operating term of 30 years.

The assumptions concerning the value development are based on Brand's indications referring to the renewal of 'services', 'space plan', 'skin' and 'site' and on Thomsen's remarks referring to the development of the amount of living area used per person and to the replacement capacity of the construction industry.

The importance scores have been deduced from the indications given by the interviewed persons, mentioned in Section 3.4.4. Due to the proportions of the importance scores, the total weighed score for quality dimensions of the 30 years old apartment approximately equals 65% of the total score of the new apartment. In accordance with that quality development, the customer value, expressed by the fair price rent, is also reduced to that level (represented in euros at the same price level in terms of purchasing power).

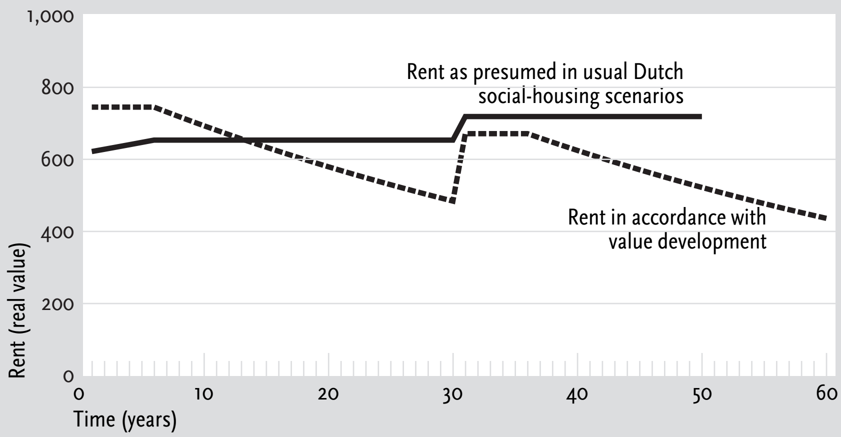
If the relative importance of all 'site' and 'structure' related quality dimensions (which are diminishing in a slower pace) had been assessed at half the percentage as assumed in the tables, the value after 30 years would have been reduced to approximately 55%. If the relative importance of the 'site' and 'structure' related quality dimensions would have been doubled, the value after 30 years would have been reduced to approximately 75%.

So, the value of a 30-year-old house for the tenant can be expected to be somewhere in between 55 and 75% of the value of the same house when it was new (measured in purchasing power). Meanwhile, the tenant is likely to judge a considerable part of the quality dimensions of the house as being insufficient. At the same time he/she may have to pay a rent that is rather high as compared to the (perceived) customer value.

3.5.3 Quality and status

As remarked in the previous section, the quality rating and importance score in the model of Gale do not determine the general price level of houses or even the price level of a certain type of houses. Indeed, houses in various locations, which are comparable as to other quality dimensions, tend to show quite different prices. According to Phe and Wakely, these differences are

Figure 3.4 Rent development in the course of time (inflation = 0%)



related to the often non-physical attributes that distinguish different levels of housing desirability, which are accepted by certain social groups, the so-called housing status, as described in Section 3.2.4 (Phe and Wakely, 2000). No research is done to what extent this housing status equals to or overlaps with the image dimension of quality (according to Garvin and Gale). It is not precluded – and on the contrary quite probable – that respondents from different social groups show, to a certain extent, varying valuations of all three of the discerned quality dimensions. Therefore, modifications in the housing status of a particular location may interfere with the value development of the concerning houses.

However, since most houses in the same neighbourhood usually have more or less the same level of quality, this interference will hardly affect the relative value (i.e. market position) of the aging houses within that particular neighbourhood. It is not likely that a particular house (or complex of houses) in a neighbourhood possesses a quality dimension that demarks this house (or complex) from all the other houses in the neighbourhood, in such a way that the valuation development of this house (or complex) will significantly vary from the other houses in the neighbourhood.

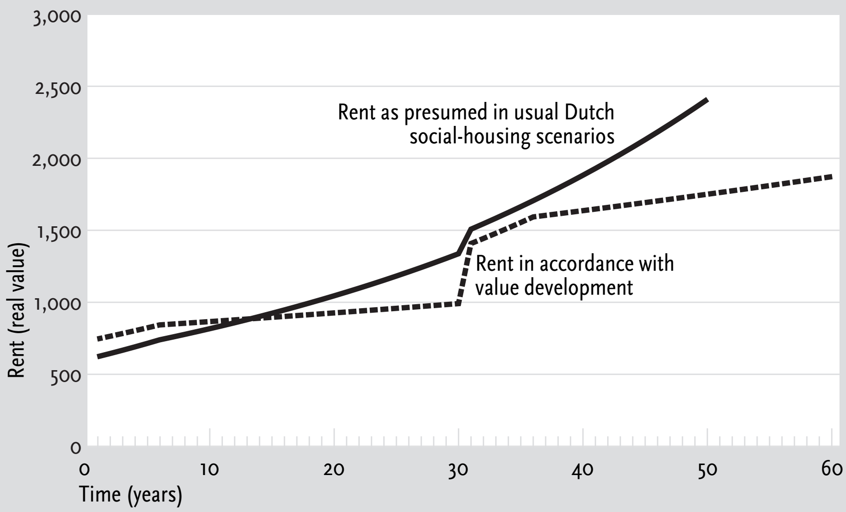
3.5.4 Consequences for rent levels

What is the effect of the described reduction of customer value for the landlord (e.g. the operating housing association)?

For the landlord, the value of the housing services, provided by a certain complex, is in principle determined by the actual rent. If this rent approaches the fair price for the dwellings, as perceived by the customers, the market position of the complex can be considered as healthy. This implies that in general the rent of houses should be gradually reduced in the course of time, rather than being increased, in order to maintain a good market position.

In Figure 3.4 the dashed line shows a possible rent development, which is gradually reduced during a period of 30 years, in accordance with the exposition in Section 3.5.2. Then, an assumed refurbishment increases the value

Figure 3.5 Rent development in the course of time (inflation = 2.5%)



of the house; the rent is increased accordingly and gradually reduced again during the next 30 years. The solid line indicates the rent development as presumed in usual (Dutch) social-housing scenarios. In these scenarios rent-increases follow inflation, which here is presumed to be 'zero'. Note that the solid line also shows an extra rent-increase for refurbishment after 30 years and that it ends after 50 years, being the assumed useful life of houses in these scenarios (CFV, 2003).

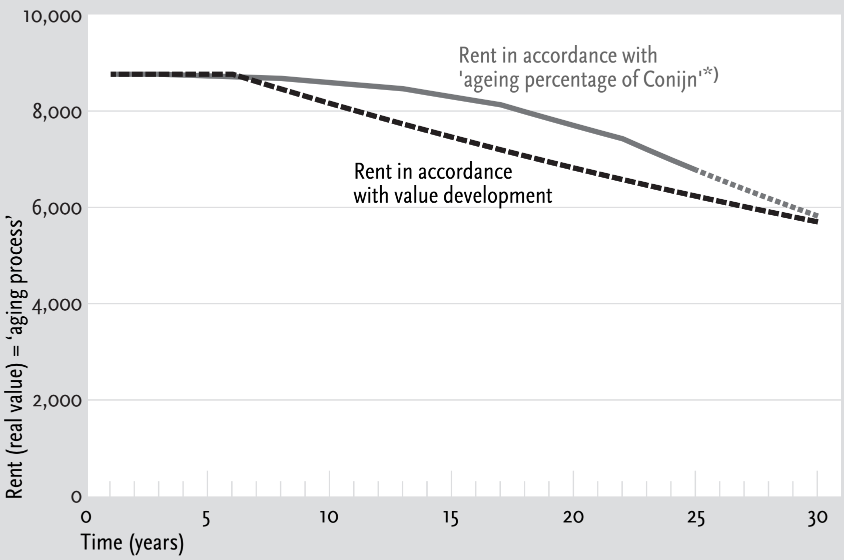
In the Netherlands, the rent of new houses, as established in the usual way, is rather low, compared to the customer value (fair price), while the rent of older houses tends to exceed the fair price. Consequently, living in older houses becomes relatively unattractive, which implies a considerable risk for landlords having older premises in a relaxing housing market. (As commercial landlords usually sell their houses before they are really old, this risk will affect housing associations in particular.) Moreover, in calculations based on these rent development assumptions, refurbishment looks like a rather unprofitable enterprise. A lot of money has to be spent in order to gain a modest rent increase. Figure 3.5 shows the same rent development, assuming an inflation of 2.5%.

3.5.5 The 'aging process' according to Conijn

Several researchers have investigated the rent development of houses using statistical methods. In literature, a high level of consensus has been achieved of the conclusion that a hedonic price equation is the most suitable procedure to assess the (price developments and the) 'aging percentage' of houses.

Using this hedonic approach, Conijn has estimated the value development of housing services related to the aging of houses in the Dutch rental sector. He has based his research on data from the Dutch Housing Demand Survey (WBO, 1989/90) processing the researched data (Conijn, 1995). While a large part of the houses older than 25 years probably has been renovated in one

Figure 3.6 Rent development in the course of time (inflation = 0%)



*) *According to the Box-Cox transformation method.*

way or another, this research was limited to houses not older than that age.

Comparing the results of Conijn to the rent development as deduced in the previous section, the conclusion should be that the relation between rent level and 'customer quality' as expressed by means of the model of Gale is at least plausible.

However, elaborating his housing services model, Conijn primarily disregards the option of improving quality dimensions by refurbishment or renovation. In accordance with the observations by Brand and Thomsen, this thesis starts from the opposite assumption (Brand, 1994 and Thomsen, 2002).

3.5.6 Value of aging houses as real estate objects

As concluded in Section 3.2.1, the value of the house as a real estate object equals (the discounted cash flow of) the net future profits. As concluded in Section 3.2.2, the bottom-line of the value of the new house is determined by the all-in construction costs of comparable new houses. This relation between future profits, value and costs, is expressed in an operating estimate. Table 3.5 shows an operating estimate according to the DCF method, using traditional assumptions concerning the operating term (50 years), rental trend (following inflation) and residual value at the end of the operating term (being equal to the land costs). The inflation rate is assumed to be 'zero' for clarity reasons; (real interest) discount rate is set at 3.0%. The monthly rent is given a value that is just enough to allow a break-even operation under these conditions. The cost-benefit figures in Table 3.5 correspond with the (imaginary) apartment that has been presented in Section 3.5.2. Clearly, the (cost-price) rent in the survey of Table 3.5 is far below the fair price rent of the new building and simultaneously far above the fair price

Table 3.5 Operating estimate method – housing associations (traditional)

land/existing property	**40,000**
construction	91,600
additional	18,400
investment	**150,000**
profit (+) or loss (-)	-
indirect yield value	**150,000**
monthly rent (1st year)	635
monthly rent (15th year)	667
monthly rent (30th year)	667
operating expenses (yearly)	1,500
refurbishment (in year 31)	65,000
residual value (basis for next term)	**40,000**
operating term (years)	**50**
inflation rate	0.0%
rent increase (until year 6)	1.0%
rental trend (after year 6)	0.0%
vacancy rate	2.0%
discount rate	3.0%

Table 3.61 Operating estimate – years 1-30 method – reducing rent/customer value

land/existing property	**40,000**
construction	91,600
additional	18,400
investment	**150,000**
profit (+) or loss (-)	**64**
indirect yield value	**150,064**
monthly rent (1st year)	745
monthly rent (15th year)	634
monthly rent (30th year)	484
operating expenses (yearly)	1,500
residual value (basis for next term)	*) **62,500**
operating term (years)	**30**
inflation rate	0.0%
rent increase (until year 6)	0.0%
rental trend (after year 6)	-1.8%
vacancy rate	2.0%
discount rate	3.0%

*) transport from – to **) transport from – to

rent of the 30 years old house. As discussed in the previous section, at this regime, the vacancy risk of older houses is fairly high under relaxing market conditions. (Actually, Figure 3.4 shows the rent development belonging to Table 3.5 and 3.61/3.63.)

Tables 3.61 until 3.63 show the alternative approach, in which rent levels gradually have been reduced in correspondence with the customer value development as discussed in Section 3.5.3. Here, the rent levels are much more in line with the expected development of the fair price rent for the apartment in the various life stages.

At the end of the first operating term of 30 years, the majority of the quality dimensions of the apartment is judged to be 'insufficient', as discussed in Section 3.5.2. For the landlord this implies an unacceptable increase of vacancy risk.

According to the model of Gale (Section 3.4.3), a housing association has several options to cope:

- The association can try to influence the tenants' preferences into the direction of quality dimensions that are relatively high as compared to the competition. However, this strategy does not offer great chances. Advertising maintenance condition, which is supposed to be quite good, is not an option, as maintenance condition is quite good for nearly all corporation houses (KWR, 1995). Advertising neighbourhood quality (if that quality is all right, as assumed here) is also practically useless, as the importance score of neighbourhood quality is very high already.
- A variation of the former option is: adjusting the target group. The housing

Table 3.62 Operating estimate – years 31-60 method – reducing rent/customer value

land/existing property	*) **62,500**
construction	54,200
additional	10,800
investment	**127,500**
profit (+) or loss (-)	-
indirect yield value	**127,500**
monthly rent (1st year)	671
monthly rent (15th year)	571
monthly rent (30th year)	436
operating expenses (yearly)	1,500
residual value (basis for next term)	**) **45,000**
operating term (years)	**30**
inflation rate	0.0%
rent increase (until year 6)	0.0%
rental trend (after year 6)	-1.8%
vacancy rate	2.0%
discount rate	3.0%

Table 3.63 Operating estimate – years 61-90 method – reducing rent/customer value

land/existing property	**) **45,000**
construction	54,200
additional	10,800
investment	**110,000**
profit (+) or loss (-)	-
indirect yield value	**110,000**
monthly rent (1st year)	597
monthly rent (15th year)	508
monthly rent (30th year)	388
operating expenses (yearly)	1,500
residual value (basis for next term)	**40,000**
operating term (years)	**30**
inflation rate	0.0%
rent increase (until year 6)	0.0%
rental trend (after year 6)	-1.8%
vacancy rate	2.0%
discount rate	3.0%
initial land costs	**40,000**

association can assign the apartment to a much smaller household (e.g. a student or a young starter on the housing market). The effect is that the quality dimension 'size as related to function' will increase considerably. Possibly, the importance scores for 'lift' and 'finishing' will diminish and the importance score for 'size' will become even higher than it is already. Together these effects may bring the overall quality score up to 'just sufficient' while no extra investment is required. For a couple of years, operating the apartment will be out of the danger zone. This sort of temporary solutions is much applied by Dutch housing associations in the early post war housing stock (Thomsen, 2002).

- The third option is to (physically) improve low valued quality dimensions, in particular those that have high importance scores. This improvement option can practically be divided into three approaches:
  - Refurbishment – A refurbishment approach of the affected (73 m^2 UFA) apartment, that combines improvement of kitchen, bathroom and services, thermal insulation and window renewal with improvement of accessibility and lift, entails approximately €54,000 for construction costs and €11,000 for additional costs, price level July 2003, VAT included (De Jonge, 2003a). By this approach, the overall quality score rises to approximately 90% of the original quality score of the new apartment.
  - Extensive renovation – This approach can bring the quality score of the apartment back to the original level of the new building, in which case the apartment's quality is completely up-to-date again. The construction costs and additional costs of extensive renovation practically equal the

costs of new construction (de Jonge, 2003b). Note that some quality dimensions of a renovated building may be higher and other dimensions may be lower than those of a new constructed building. The decision whether to apply extensive renovation or new construction is, therefore, related to the required quality specifications.

- Redevelopment (through demolition and new construction) – This is the final option for coping with obsolete dwellings. Next to redevelopment resulting in new residential buildings, also other destinations may be considered.

Table 3.61, 3.62 and 3.63 show that the value of the apartment at the end of each (30-year) term is much less than the 65% of the value at the beginning of the term that one might have expected on the basis of the discussion in Section 3.5.3. This difference is caused by the fact that the value of an apartment as a real estate object differs from the value of the housing service that is provided by the apartment. For both the housing service and the real estate object, the statement made in Section 3.2.1, is valid: 'All facts, concerning the object, which have occurred prior to the actual situation, are not relevant anymore.'

For the housing service this means that its value equals the fair price for the service as provided at the very moment, having the quality dimensions, 'as perceived by the customer'. This fair price rent indeed approaches the indicated 65%.

For the real estate object the statement implies that the value of the apartment equals the (maximum) future profits it can provide. As discussed above, at the end of the 30 years period, several interventions are possible, which entail different values for the existing apartment. For each option, the value of the existing apartment can be deduced according to the following equation:

$$V_e = V_n - C$$

In this equation V_e represents the value of the existing apartment, V_n represents the value of the new dwelling (or other real estate object), which is created by the intervention, and C finally represents the costs, which are entailed by the affected approach (being the sum of the eventual demolition costs, the construction costs, either related to new construction or to renovation, and the additional costs).

The value of the existing apartment (in euros) has been calculated by applying the equation to the various options:

Redevelopment:	V_e = 150,000 – (5,000 + 91,600 + 18,400)	= 35,000
Extensive renovation:	V_e = 150,000 – (91,600 + 18,400)	= 40,000
Refurbishment	V_e = 127,500 – (54,200 + 10,800)	= 62,500
Second time refurbishment	V_e = 110,000 – (54,200 + 10,800)	= 45,000

Refurbishment and renovation at The Hague.

Note that the highest result determines the value; this is the 'best opportunity' for the property. The other options should be considered to be waste of capital. Note also that both the (final) value and the costs related to the various options are determining the (residual) value of the existing apartment. The assumed residual value, in its turn, is part of the 'future profits' of the new apartment.

3.6 Summary and conclusion

Exploring the value of houses has started with a theoretical exposition that can be summarised in the following statements, which are valid simultaneously:

- Value of houses is determined by (discounted cash flow of) future profits.
- Value of houses is related to the (actual) all-in building costs of houses.
- Value of houses is related to desirable characteristics/performance.
- Value of houses is gradually diminishing due to innovations.
- Value of houses is fluctuating by a combination of maintenance and loss of performance.
- Value of houses is related to their location in the context of trade-offs based on status and the social acceptability of dwelling quality.
- Value of houses is influenced by housing market factors (e.g. general shortage of housing) and other economic factors (e.g. interest levels).

For the producer, being a real estate development company or a contractor, the value of a dwelling simply is the sales price. The (all-in) production costs form the bottom-line for the value of a product or service. If the production costs exceeded the value, the product or service would not be on offer.

Most of the approaches and definitions of value, which are commonly used in the countries of the Western world for the appraisal of houses, are applicable in the context of the EVR as far as the production phase is concerned. However, sustainability optimisations concerning the operating phase need further consideration.

As decisions in design processes mainly refer to physical building characteristics of houses, research has been directed towards determining a relation between these characteristics and the value of houses.

In that context, Garvin's ideas concerning quality dimensions are (tentatively) elaborated for the Dutch housing sector. Essential for these quality dimensions is that they are determined by product characteristics 'as perceived by the customers'. In the idea of Garvin, quality can be judged by the customers only. As to housing services, the value for the tenants, being the customers, can be expressed by the fair price rent. In the customer value model of Gale, this value/fair price rent is related to the customers' appraisal of the various quality dimensions of the affected dwellings.

This elaboration in its turn has been connected to Brand's observations referring to the periodicity of adaptations in existing dwellings (in several countries) and to Thomsen's remarks referring to the development of the amount of living area used per person and to the replacement capacity of the construction industry in Europe. On this basis, a model has been produced concerning the quality and value development of aging houses. The estimated value development of housing services based on this model has been concluded to be consistent with Conijn's findings referring to the aging of houses in the Dutch rental sector.

The quality dimensions tend to be reduced in the course of time. After a period of 30 years following the initial construction of a dwelling, the total quality rate, and by consequence the customer value, will be approximately 65% of the quality rate, respectively the customer value, of the new dwelling. Modification in the housing status of a particular location, as described by Phe and Wakely, may interfere with this value development. However, since most houses in the same neighbourhood usually have more or less the same level of physical quality, this interference will hardly affect the relative value (i.e. market position) of the aging houses within that particular neighbourhood.

The value of a dwelling as a real estate object for the landlord equals the (discounted cash flow of the) net future profits of that object. Especially for houses at the lower price levels (in general the social sector), it is recommended that the net future profits are estimated, considering the above mentioned reduction of the quality rate for the housing services, which are provided by the dwellings. It should be kept in mind that after a term of 30 years, the quality of the dwellings will be perceived (by the customers) as being insufficient, and a reinvestment is probably required for further operation. The (residual) value of the dwellings at that moment should be estimated based on the expected reduction of the various quality dimensions of the provided housing services (using the model of Gale) and the possibilities of recovering quality, and value, by applying refurbishment, extensive renovation or new construction. So, the residual value at the end of the operating term is produced by the difference of the value of the dwellings after an intervention at that moment and the (all-in) costs of the very intervention.

$V_e = V_n - C$

In which V_e = (residual) value of the existing dwelling
V_n = value of the new dwelling created by the intervention
C = all-in construction costs of the intervention

By these conclusions a model is completed, which relates the concept of value in the context of the EVR to the conceptual framework of architects. On the one hand architects can use this model for analysing, which quality dimensions should be addressed in order to add (customer) value to their designs. On the other hand the model provides an insight into the relation between the development of the value of houses and the reduction of the various quality dimensions in the course of time.

4 Design and development processes

What requirements are set by design and development processes for a decision-support tool referring to eco-costs in particular during the early process stages? This chapter deals with that question.

4.1 Introduction

It is evident that a tool, which is intended to support building design and project development, should be connected to the methods and procedures involved. Often, such a tool actually is developed based on a criticism of exactly these very methods and procedures. According to the viewpoint of the producer of such a tool, the process should be different from the way it actually is on that moment.

However, a complicated process, as in building design and project development, is effectuated on the basis of many considerations, interests and relations with other processes. Such a process is not changed just like that, while some new instrument is put on the market. At best, the provider of a new tool may expect that applying the tool will adjust the process to a limited extent in the long run.

The model of the Eco-costs/Value Ratio (EVR), which should provide starting-points for optimising the environmental performances of a building design, is composed like an estimating tool. It actually is an estimating tool, as it provides a method to estimate eco-costs (see Chapter 2). It may be expected that applying such a tool will bring similar problems as are experienced at applying traditional estimating tools.

In order to achieve a satisfactory implementation in development projects, the EVR model should be adapted (if necessary) according to the considerations above. Consequently, in this chapter research is directed to housing development and design processes, concerning both new construction, renovation and refurbishment, and to the way estimating tools are (supposed to be) applied in these processes.

Both architects, being the primary designers of building plans, and their clients, being the final decision-makers in the projects, together can be expected to control the choices made in building development processes. Decision support tools should be tuned to these groups in the first place. So, the approach of the development and design processes in this study emphasises the position of these groups.

In various countries different formal building development processes are used to structure the decisions that are needed to compose building plans. Therefore, this chapter continues with a review of the formal development processes in several countries, followed by an exposition of some characteristics of the design process that are important for the way in which cost data should be presented to architects in order to support this process. Next, available methods and tools for estimating in housing development projects are explored.

Based on the conclusions of these investigations, a new model for estimating is developed (or rather an existing model is adapted).

4.2 Development processes

4.2.1 Development process in the Netherlands

In the Netherlands, architect's commissions are usually based upon Standard Conditions (SR). These conditions discern a series of fixed stages and duties for an architectural development project, starting with the preliminary design stage, followed by the definite design, the preparations for building and the pricing and contracting stage. Usually at this point, the development process is considered to be finished, while the actual construction activities are started. However, since architects often are supposed to supervise these construction activities and give various instructions on behalf of the client, also this realisation and completion stage is covered by the SR (BNA, 2002 and Appendix 5).

The SR does not discern an initiatory stage, in which the client is assisted in formulating requirements for the intended building. Yet, preparing a schedule of requirements, also called a brief, is generally considered to be an important activity in development processes in the stage preceding the preliminary design.

In the majority of construction projects, next to architects, several other consultants are commissioned, e.g. structural engineers, consultants for mechanical and electrical systems, or cost consultants. These consultants specify their activities in the RVOI referring to practically the same process stages as the architects do in the SR (KIVI, 2001 and NVBK, 2001). Unlike the SR, the RVOI does comprise a specification of the initiatory stage, here called investigations. Reason to do so presumably is the emphasis of the RVOI, which traditionally refers to other tasks and other (often more specialised) structures than the SR does. However, since 2002, architects and building consultants in the Netherlands have been engaged in developing a common standard contract for all professionals in building development projects.

According to Spekkink, preparing a brief (schedule of requirements) is not just a single action in this stage, but a process of continuing refinement throughout the development of a building plan up to the definite design. In the initiatory stage the brief should be tested by feasibility studies in terms of economic outcome, (urban) planning possibilities and environmental impact. In every following stage the specification of the brief should respond to the proceeded detailing of the design and the other way around (Spekkink, 1995).

In this context, cost estimating is considered to be an instrument for assessing the conformance of the design to the financial constraints as indicated in the brief, following the unfolding specification levels of the development process.

The ideas of Spekkink are not new for the Dutch building industry. In the 1960s and 1970s the so-called Development Cycle for Low-rise Housing ('Ontwikkelingscyclus Laagbouw') indicates a process in which every stage is started with programming activities and finished with an evaluation by means of an estimate (COWOM, 1974; Bouwcentrum, 1981a, 1981b and 1981c).

In the preparations for building stage, the design drawings are completed by specifications of the construction works in text. These production specifications are usually written in accordance with the STABU specifications systems for residential, non-residential and non-civil building works (STABU, 2001).

4.2.2 Development process in the United Kingdom

In the United Kingdom, the Standard Form of Agreement (SFA) discerns more or less the same tasks for architects as the SR does in the Netherlands. In the UK, however, much more emphasis is found on feasibility studies and scheduling requirements in the early process stages (RIBA, 1999 and Appendix 5).

In the British scheme, the requirements to be met by the design are primarily outlined in the Strategic Brief and later on specified in the Project Brief. The development of this Project Brief is not completed before the detailed proposals stage. In any of the stages from outline proposals to production information, estimates of building costs are required in more and more specified form to the end of the process. In the tender documents phase either the architect or the quantity surveyor should make a final estimate for the appraisal of the tenders' submissions.

So, at least on paper, in the UK the emphasis is much more on brief and estimating activities than in the Netherlands. On the other hand, less effort seems to be spent on preparing elaborated production specifications.

4.2.3 Development process in Germany

Formal schemes in Germany are slightly different again (Bundesregierung, 2003 and Appendix 5).

In the pre-design stage, architects are supposed to make feasibility studies, requirement schemes and financing schemes. In the design stage a detailed estimate of building costs according to DIN 276 is required (DIN, 1993). In the tendering and contracting stage, a final estimate and an appraisal of the tenders' submissions are anticipated.

4.2.4 Development process in the USA

In the United States, the Local Initiatives Support Corp. advertises a structured approach to affordable housing project development, which is partly based on Demkin's '*Architects Handbook* (LISC, 2004, Demkin, 2002 and Appendix 5).

In the concept phase, preparing a brief is referred to as 'programming'. This important activity in that stage, should be reviewed in the pre-development phase with potential occupants, community groups and other stakeholders. In the development phase ongoing consultations between the project team and the community are advised. So, like in the UK and Germany, in projects in the USA preparing a schedule of requirements seems to be an ongoing effort throughout the development process to the completion of all design activities.

One of the recommended project management activities is conducting cost analyses early and often. For the affordable housing projects cost estimates are recommended at a minimum of seven separate times during the development process, from the early completion of the site evaluation throughout the subsequent process stages up to the bidding process. These cost estimates should be made in a way that they build on each other over the various stages of development.

4.2.5 Renovation

Maintenance and renovation form a very important and ever growing part of the construction market (CBS, 2003). However, in the reviewed documents concerning formal project development schemes for architects, renovation does play a significant role. Apart from the odd remark about investigating the structural and maintenance situation of existing buildings and the architectural particularities in restoration projects (of cultural heritage), the SR does not pay much attention to the special problems and possibilities, which are offered by the presence of an 'existing situation' of a building and its residents. Neither did the documents from the other countries.

In general the sequence of process stages will not be affected very much anyway. Some phases may take (relatively) more time; other phases may just speed up. However, (estimating) tools should clearly anticipate the particularities of renovation to be able to play a meaningful role in the development of these projects (Winket, 2004).

4.2.6 Requirements for estimating tools based on the development process

In the reviewed process schemes from several countries, a variety of formal process stages is found. However, functionally the overall impression is that

Table 4.1 Prevailing sequence of process stages in the development process in the Netherlands, the UK, Germany and the USA

Development process	Stages	Programming & design objectives	Decision entities	Examples
Initiative	Initiative Feasibility study Project definition	Programme & Budget Financing	Overall project	Strategic brief
Design	Master plan	Siting	Site	Orientation Roads
	Preliminary design	Overall building appearance	General building concepts	Open-plan house Two-bedroom apartment
		Main lay-out	Large functional and spatial entities	Living room Bedroom Kitchen
		General concept of structure and services	Building elements	Floors Walls Windows Electrical system
	Definite design	Specified building appearance Specified structure and services	Specified elements	Concrete floor Brick wall Wooden window
Specifications	Construction information	Detailed building specifications Construction documents	Specifications	Reinforced structure in accordance with the structural engineer's specifications Glazed wall tiles 150x150, white
	Pricing & contracting			
Preparation	Planning/mobilisation			
Construction	Realisation Completion/acceptance Defects liability work			
Operation	Building management			

all processes follow more or less the same scheme from a global setting of objectives and targets – concerning the whole project, the site, occupants and overall budget – to a more and more detailed elaboration and specification of building design. Finally, all processes end up with contracting, construction and completion of the building project.

In all countries, development is seen as an iterative process between aspirations and goals for the project and the possibilities of the available budget. Early documentation of overall project targets in an outline *brief* and subsequently gradual elaboration in more detail should result in optimum adjustment of requirements and design solutions.

Attention to costs from the earliest stages of the project should ensure that the evolving design can be built for the available *budget*. Some trade-offs will be inevitable as the process unfolds, but if costs are analysed and controlled on an ongoing basis, these trade-offs can be minimised so as not to affect critical design components (LISC, 2004).

Table 4.1 shows a survey of the prevailing sequence of process stages in the reviewed building development schemes. The emphasis of programming and design in the different stages is presented in the second column. In the third column (the scales of) the main decision entities are indicated. All of them are accompanied by an example.

Brief and estimating tools should be developed in connection to each other. The brief – in its various stages of elaboration – should contain budget information adjusted to the degrees of specification that are characteristic of the actual process stages. Estimating tools should be elaborated in a way that allows them to evaluate design decisions on the levels, which are characteristic of these process stages.

Following the development process as presented in Table 4.1, in the project definition stage, estimating tools should refer to the overall project. In the preliminary design stage, estimating tools should refer to construction costs of general building concepts, large functional and spatial entities and (general concepts of) building elements. In the definite design stage, they should refer to costs of specified elements, and in the construction information stage, they should refer to the production specifications.

4.3 Building design processes

4.3.1 Design as problem analysis

Building design processes are very complex. In this thesis, theoretical reflection upon design processes will be far from exhaustive. However, it may be sufficient to question how to communicate cost data to architects, in order to let these these be useful in the different stages of the design process. The exposition will successively discuss design as problem analysis, the role of experience and knowledge and the hierarchical structure of the design problem.

In 1985 Boekholt describes in the *Vademecum for Architects* the design process to be considered as a complex process, composed of a number of basic process cycles. These process cycles are executed more or less implicitly

Eye-catching villa at Klein-Zundert (new construction).

or explicitly and they result in 'ideas' (in the mind of the designer) or in 'representations' (on paper or monitor). Architectural design deals with problems that are complex with respect to both content and structure. Designers will try to divide such problems into a number of sub-problems with a simpler structure. This way, for any of these sub-problems more precise targets can be formulated and the information concerning the building project can be made more accessible and in particular more workable. The number of possible solutions can be restricted and a limited number of criteria can be developed to evaluate the solutions. Meanwhile, it is important that the distinct sub-problems stay connected, or can be adapted to each other.

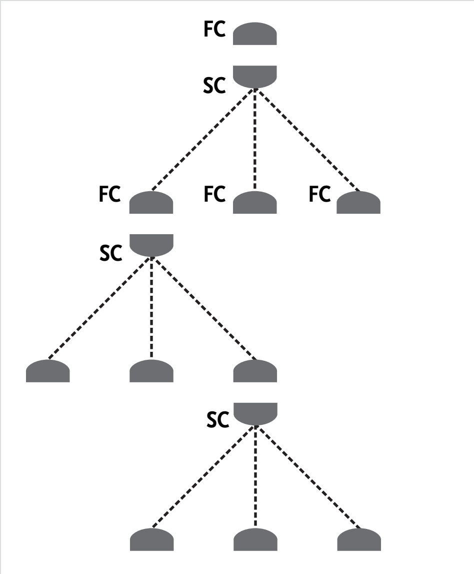
Boekholt states that designers can only solve design problems by subsequently solving sub-problems on different levels. In building design practice this means that architects discern design problems according to different scale levels, like the building site, the whole building, a room or a constructional detail.

An important tool for architects to solve design problems (on any level) is drawing alternatives. This can be done for two reasons. The first one is to find one or more acceptable arrangements of elements within a given situation. The second one is to evaluate a new spatial concept or a given spatial situation. If requirements are defined implicitly, i.e. if the situation, the elements and the allocation rules only exist as ideas in the mind of the designer, sketching design alternatives usually will be done in rough outlines. Frequently architects will evaluate an alternative while sketching, and the sketch will not be completed. The mere emerging of the representation brings up new ideas. Such an implicit way of executing this procedure is often shown in the beginning of the design process. In later stages architects will tend to use more explicit definition of targets and criteria (Boekholt, 1985).

4.3.2 The role of experience and knowledge

The description of the design process in the previous section does not comment on the capability of architects to learn from (their own) experience and

Figure 4.1 Composition hierarchy



FC = Functional Concept
SC = Solution Concept

Source: Woestenenk, 1999

to use results from research done by others (knowledge). This capability is shown by Lans. In her approach of the design process as an empirical cycle she describes the beginning of the process as decomposing the problem in order to be able to define objectives and constraints. This process of defining leads to confinement of possible solutions. Next the architect deletes the solutions that do not fit at all. The choice of which solutions are impracticable and which are promising, is to a large extent based on the architect's experience and knowledge. This experience and knowledge often refers to combinations of solutions on different levels (Lans, 2001).

In design practice, this way of using experience and knowledge referring to complicated subjects can be seen pre-eminently, when in early planning stages architects use general building concepts as starting points for their sketches. For instance, an urban villa or a penthouse can be seen as suitable for a certain schedule, while a gallery flat is judged not to offer the required performances for that schedule.

4.3.3 The building as a composition hierarchy

Woestenenk describes in *the LexiCon* the design and construction (of an airport) as the process of transforming a 'virtual airport' into an 'as-built airport'. To work out this idea he uses the distinction between functional concepts and solution concepts (Giehling, 1988). The idea of a solution concept as opposed to a functional concept fits with the idea of 'design' as opposed to 'requirements'. In other words a design can be seen as a solution concept that is proposed as a solution for a set of requirements, which in their turn can be seen as a functional concept.

As a built object is considered to be a composition hierarchy of functional concepts and solution concepts, as shown in Figure 4.1, the design process can be seen as a process of trying out solution concepts as proposed for functional concepts on different levels in the hierarchy (Woestenenk, 1999). This is actually in line with the description of Boekholt. It even goes a step further than that, since in the idea of Woestenenk the very character of the building, as a composition hierarchy, urges the architect to resolve design problems by identifying them as combi-nations of problems on lower levels.

Observations in construction cost consultancy practice for more than 25 years confirm that indeed architects do approach design problems this way.

4.3.4 Design process not strictly top-down

Since experience and knowledge play a role, as Lans points out, part of the relations between functional concepts and solution concepts are already established in advance. Among other things, this allows a design process not to go strictly top-down all the time. Architects may focus on special parts of the design, developing other parts in later stages and leaving still other parts to ‘standard’ solution concepts. The presentation of cost data to architects should respond to these findings, which means that cost data should be presented in a way that they can be used on different scale levels simultaneously.

4.3.5 Requirements for estimating tools based on the design process

Due to the character of a building (or a complex of buildings), being a composition hierarchy of functional concepts and solution concepts, architects can (and do) resolve design problems on a certain level in this hierarchy by identifying them as combinations of problems on lower levels. In the formal development process stages this practice is recognised in the sequence of strategic brief, responded to by a preliminary design, in its turn responded to by an elaboration of more detailed requirements etc.

While the design process allows an architect quite well to go up and down the composition hierarchy of the building (or complex) in order to evaluate several design alternatives on different levels, the sequence of formal development process stages is much more static. When in practice a certain phase is completed by an official client’s approval, only very severe arguments can make the process return to that phase, otherwise, economic interests of the involved parties would be damaged too much. This static character of the development process sequence, as compared to the sequences in the design process, urges architects and other professionals in building development projects to be quick and lean in going ‘up and down the design ladder’ to evaluate possibilities of interesting design alternatives on different scale levels. Especially, in the early stages of project definition, master plan and preliminary design, architects may want to evaluate several alternatives (for features on lower scale levels) on a very quick basis, because budget for extended research is usually not available. Estimating tools should be able to follow this quickly going ‘up and down’. In other words they need to offer ‘ready and easy’ cost information that can be used to evaluate design alternatives on different scale levels simultaneously, connecting the information on the discerned levels in a way that excludes double counting or omission.

Example of problematic cost estimating on different scale levels

An architect is commissioned by a housing association to develop a number of renovation projects for several apartment blocks built in the 1950s and 1960s. In the project definition stage, the architect estimates the construction costs based on cost indicators per m² gross floor area derived from experience with previous renovation projects of the same type. In one of the apartment blocks, the architect sees an opportunity to enhance the housing quality by adding balconies to the end walls of the block. The client is pleased with this proposal. However, she wants to be sure that the intervention will not exceed the available budget. Therefore the architect has to make some additional calculations to estimate the costs of adding balconies and enlarging the (window) openings in the end walls of the block. Doing so, the architect has to make sure whether, and if so to what extent, the costs of adding balconies and enlarging window openings are already covered by the cost indicators per m² gross floor area. Otherwise, considerable miscalculations may occur, as is shown in the list below.

At no.1 the costs per m² are mistakenly assumed to be exclusive of the costs of a balcony and ancillary windows. At no.2 the costs per m² are reduced by €60, being the costs of a balcony and ancillary windows already in the cost indicator. At no.3 the cost difference per apartment is calculated, including VAT and fees etc

Costs per apartment in euros (2004)

1. Costs/m²	80 m²	760	60,800	
Window	4 m²	600	2,400	
Balcony	1 unit	2,800	2,800	
Construction costs excl. VAT			66,000	
VAT 19%			12.540	
Construction costs incl. VAT			78,540	
Fees, etc. 15%			11,781	
Total per apartment				**90,321**
2. Costs/m²	80 m²	700	56,000	
Window	4 m²	600	2,400	
Balcony	1 unit	2,800	2,800	
Construction costs excl. VAT			61,200	
VAT 19%			11.628	
Construction costs incl. VAT			72,828	
Fees, etc. 15%			10,924	
Total per apartment				**83,752**
3. Difference per apartment				**6,569**

4.4 Classifications

4.4.1 The changing character of building production in the 20th century

The changing character of the construction industry in the beginning of the 20th century induced the development of new ways to look at the value (quality) and the costs of buildings, especially designed to be of use in the development process of building projects.

In the 20th century, in Europe and the United States, new buildings started to be much more complicated than they used to be in the previous centuries. In Europe not only bigger buildings and buildings with various functions were constructed, but because of the fast population growth – especially after the Second World War – thousands of dwellings were to be built in large projects. As a consequence the development process became also more and more complicated. A need for instruments to serve good communication about building materials and components in several stages of the development process emerged from this complexity.

Also estimating building costs in early stages of project development became problematic. Traditionally, cost calculations were not made before completion of the building specifications of a designed project. The composition of building costs in these calculations followed the specifications of the various types of materials and labour that had to be used for construction. This way of estimating building costs was not very helpful any more in the early process phases of the ever more varying, modern, large-scale projects. Right in these early process phases, in which little knowledge about materials and other specifications of the project is available, the need for well-specified quality and cost information became evident.

To solve these problems, architects and managers started to develop systems for classifying construction information (Wright, 1998). One of the major effects of these activities has been the reform of quality and cost information from a constructional planning instrument to a design and decision support tool in the development process.

4.4.2 The SfB-system

One of the most successful initiatives to the organisation of construction information is the classification system of the 'Samarbetskommittén för Byggnadsfragor' (Committee for Building Problems) in Sweden. From 1947 till 1949 this committee developed a standard classification system for building information: the SfB-system. The system consists of a set of classifications using different ordering principals for various purposes. It can be and has been used for the classification of product information, construction specifications, drawings and library contents. In the 1950s and 1960s several countries in Europe have adopted this SfB-system.

The so-called 'Table 1: Functional Building Elements' of the SfB-system in its various forms is still used nowadays for cost information concerning building projects, especially in the design stages. This system is currently being used in Sweden, the United Kingdom, Norway, Finland and the Netherlands.

The most recent version used in the Netherlands is described in 'Elementenmethode '91' (Jongkind, 1991). The ordering in main elements is still practically equal to the ordering that is used in the UK-version (CPIC, 2003).

4.4.3 Other element classifications

Though the architects in the United Kingdom (RIBA, 1969, 1976) recommended the use of the SfB-system, the Chartered Surveyors (RICS) thought this method not practical. In 1969, the RICS published its own element classification, which has been used ever since by its Building Cost Information Service: the 'Standard Form of Cost analysis' (RICS, 1969, 1987). In general, the SFC consists of the same elements as the SfB-system. The main differences refer to the way in which the elements are arranged. The RICS offers a clear table, which relates the SFC to the SfB codes.

In 1997, CPIC (Construction Project Information Committee) published still another element classification. This classification is not connected to either of the above mentioned ones, but is a part of 'Uniclass', a classification for the more production-related parts of the construction industry (CPIC, 1997).

In Germany, again another element classification is used. Here the Deutsches Institut für Normung has published 'DIN 276 Kostengliederung' (DIN, 1993). This classification does not only deal with building elements, but covers the overall building investment. So, it also contains elements of land acquisition and site preparation as well as additional project costs. The actual subdivision of a building into elements by this classification shows only minor differences from the SfB-system or the SFC elements. Again, the main differences refer to the way in which the elements are arranged. The DIN 276, however, is slightly better specified than the other European classifications.

In Switzerland, the 'Schweizerische Zentralstelle für Baurationalisierung' is promoting an element method (Goeggel, 1996) that is in many aspects comparable with the German system, but it has been worked out in still a different way.

In the United States and Canada, 'Uniformat II' appears to be the generally used classification system (Charette and Marshall, 1999). In Australia, the Australian Cost Control Manual (ACCM), owned by the Australian Institute of Quantity Surveyors (AIQS), is used for cost planning and similar purposes in building development projects (Wright, 2003).

4.4.4 Classifications for renovation purposes

In order to organise construction cost data, most element classification systems primarily have been elaborated for application in projects of new construction only. Using the same classification for both new construction and renovation projects has not been taken for granted immediately, while distribution of costs over several building parts in renovation usually is quite different than in new construction. During the 1970s and 1980s some classifications have been used in the Netherlands, which were developed for renovation in particular. The municipality of Rotterdam used the Q-and-Q system (Quantities and Qualities system), the Ministry of Housing, Spatial Planning and the Environment used the SROW system (Standard References for Maintenance and Housing Renewal). However, eventually these systems never have been applied on a wide scale.

Based on the concept of life cycle costing (see 4.5) and the need to consider the whole life cycle of buildings and building elements from the viewpoint of sustainability, a separate classification for renovation should be rejected anyway. However, in general any element classification should contain possibilities to specify and evaluate interventions in existing buildings.

4.4.5 Efforts to improve classification

For many years efforts have been made to arrive at internationally agreed tables for classification of construction information, but progress has been slow. One of the more recent efforts on an international level has been carried out by the International Organization for Standardization (ISO), committee ISO/TC59 (ISO TR14177, 1994 and Wright, 1998a + b). According to the ISO committee their system can classify all possible building components (objects) in a unique way, so, that all data concerning these components can be stored in an information base, ready for reuse in another phase of the same or a different project.

The developments concerning this system are still on a rather theoretical level. Moreover, the major aim of this system seems to be an unbiased identification of building parts rather than a tool for architects to structure their design decisions.

On a more practical level, in the Netherlands, the NEN standard 2634 has been developed in order to improve communication between consultants and stakeholders concerning quality and cost data in building development projects (NEN, 2002). The NEN 2634 mainly has been based on the NL-SfB elements classification, which is used (or at least known) by the majority of architects and cost consultants in the Netherlands. The NEN 2634 provides a superstructure for this elements classification that allows standardised aggregations of data, which are considered to be useful and practical by the profession.

On the one hand the 'Elementenmethode '91' version of the SfB-system may be considered to be part of architects' practical knowledge in the Netherlands, and on the other hand the Element Clusters (superposed on the elements by the NEN 2634) are closely linked to the way the construction industry categorises building projects into foundation, structural work, fitting-out, services and finishing works.

4.4.6 Consequences for new models and tools

In various countries, architects and cost consultants use different classifications to communicate costs and qualities during the building development process. The differences between the various classifications – especially within Europe – are not very big. Some may be better specified than others. They all may have their advantages and disadvantages in practical use. However, if a company, let alone a country, decides to change the classification it uses, large amounts of money have to be spent on modifying computer models, documents, procedures etc. and on the retraining of the involved professionals. So the interests of companies and countries in sticking to 'their own' classification are huge.

In developing new models and tools, these interests should be kept in mind very well. This means that a precondition for a new model or tool for cost estimating or eco-cost estimating is that it has to be adaptable to different classifications of building elements.

The model that is presented in this thesis meets this precondition, since it is based on the general idea of a building as a composition hierarchy of functional concepts and solution concepts. The model is elaborated for use within the context of the SfB-system according to the NEN 2634, being the almost generally accepted standard in the Dutch building development industry.

4.5 Estimating methods

4.5.1 The three starting points for estimating

The way in which an estimate is organised is strongly determined by the viewpoint of the estimator towards the transfer of cost information (Swets, 1993):

The client is primarily interested in the final results of designing. He is demanding rooms and functions in the first place. As far as the client is concerned, estimating should provide information that is attached to the rather general budget targets drawn up in the initiatory phase. Consequently, his need for cost information is directed to decision units on the level of spatial and functional building sections. From these needs cost information is organised in the form of cost indicators related to functional units (office working area, hospital bed, room unit).

The architect and other consultants transform the client's requirements into a building design, using walls, floors, roofs etc. The most appropriate estimating method for these participants is evidently based on the approach of a building as a combination of 'functional construction parts'. This approach has led to the method of the elemental bills of quantities.

The construction company (the contractor) has quite other needs. In the tendering and pricing stages, his estimate is preferably organised in accordance with the construction tasks as laid out in the building specifications. In the preparation and construction phases, cost calculation should be related to planning and sequences of work.

Related to the subject of optimising eco-costs in the (early) design stages, this study mainly emphasises the client's and architect's approaches of estimating.

4.5.2 Elemental bill of quantities

According to the various element classifications, several types of elemental bills of quantities have been developed. They all produce estimates based on quantities of elements dimensioned from design drawings in a more or less systematic way (Dubbeling, 1999).

In practice, bills of quantities produced in this way cannot be used in design processes before halfway the preliminary design stage. Table 4.1 shows that earlier in the process, a simple lack of sufficiently specified data concerning the design prevents architects and consultants from making such estimates.

The basic idea behind estimating based on elemental bills of quantities, is the assumption that varying technical solutions for a functional building element are more or less competitive for quality as well as for price. According to this assumption, a functional defined building element is corresponding with a certain price level. Since the measure of specification of the function confines the range of the technical solutions, the accuracy of an estimate based on an elemental bill of quantities depends upon the measure of specification of the required functions (i.e. quantities and functional qualities of the elements). The number of principally varying technical solutions for a certain element is limited (within a building market region, e.g. the Netherlands or West Germany). The solution for the whole element in a design, however, can consist of a practically infinite range of combinations of these technical solutions. In the actual design practice in West Europe, this means that unit prices on the level of the whole elements of various building designs may differ to a large extent. This implicates that estimates based on quantities of elements, which are not specified on the level of technical solutions, are virtually useless in nowadays design practice.

4.5.3 OC/Bouwcentrum model

In the context of the Development Cycle for Low-rise Housing, the Bouwcentrum ('Building centre') at Rotterdam developed a computerised estimating model (Bouwcentrum, 1981a, 1981b and 1981c), which provided building cost data of (terraced) houses with varying sizes and block lengths. The model was based on elemental bills of quantities that had been prepared for schematic designed houses in three different types. For a period of approximately 10 years the OC/Bouwcentrum model could function quite well because of the rather large amount of uniformity in house-building during those years. By the end of that period, design practice was inclined to much more varying building forms, materials and finishes. Hence, an approach based on assumed standardised qualities was hardly applicable anymore.

4.5.4 Project sections model

In the 1980s the Municipality of Rotterdam developed and used the so-called 'Project Sections Model' ('Projectdelen methode'). In this model construction costs are designated to areas, which are characterised by their functional use, e.g. 'dwellings in several types', 'storage areas' and 'access and circulation system'. If a building project is divided into these types of areas, implementing the construction costs of some specified building parts in an estimate turns out to be problematic. Consequently, next to the functional areas, these specified building parts are discerned as 'project sections' in the model (Ter Haar, 1991 and Swets, 1993).

In the 1990s this model was used in other building projects that integrated housing development with developing shops. In 2002 the model was adapted for improved use in all kinds of complicated building development projects (De Jonge, 2002b).

In practice, the project section model is used in combination with elemental bills of quantities prepared for the discerned project sections. Successful appliance in earlier process stages can only be achieved under two conditions:

- sufficient uniformity concerning the project as composed of the project sections;
- sufficient uniformity concerning the project sections as composed of the involved building elements.

Both conditions are questionable in the early design stages. Especially in housing projects, in which architects are willing to investigate the options for

Apartment building at Venray (new construction).

sustainable building, variation of building forms and qualities of materials can be expected. Therefore, the project sections model is not the first choice as for a method of estimating in the context of eco-costs.

4.5.5 Life cycle costing

Life Cycle Cost (LCC) Analysis is a method of analysing the cost of a system or a product over its entire lifespan. The objective of performing an LCC analysis should be to choose the most cost-effective approach for using available resources over the entire lifespan of the product or system. LCC is especially useful when project alternatives that meet the same performance requirements, but differ with respect to initial costs and operating costs, have to be compared in order to select the one that maximises net savings. In particular LCC is applied in order to evaluate alternative solutions for heating and air conditioning systems in combination with e.g. more or less insulated elevations and windows (Boussabaine, 2004 and Fuller, 2003).

More sophisticated forms of LCC are used by the avant-garde of consultants in specialised projects or in research. In 'ordinary' housing projects, LCC techniques are used by housing associations in performing so-called operating estimates (Gruis, 2001).

4.5.6 Problems and practical solutions

It is widely acknowledged that the decisions with the highest economic impact in building projects are made in the first stages of the development process (Bredero 1975 and Kranendonk 1999). In these stages, general cost indications are needed to evaluate the decisions which are at stake (see Table 4.1), whether they may refer to traditional construction costs, life-cycle costs or eco-costs.

The cost indications required in this stage should correspond with the general building concept and the overall size of the projected building (Gerritse, 1999). As for traditional construction costs, general cost indications may be derived from (large scale) cost surveys concerning various building types (CBS, 2003).

However, these indications provide data concerning average building costs in certain sectors. For specific projects such averages may not be applicable at all. As for life-cycle costs or eco-costs, these kinds of databases are not even available whatsoever.

So, more specific cost information is needed than is provided by the large scale cost surveys. Can estimating tools as described in the previous sections, provide the required accuracy?

The main problem of applying the existing estimating tools, especially in the early stages of the development process, is situated in the large variation of forms and materials in the actual building design practice. In the development process of a specific building project, this variation makes the accuracy of cost estimating, on aggregation levels higher than technical solutions, very doubtful. Making an elemental bill of quantities, for instance in the project definition stage or the beginning of the preliminary design stage, would require so many assumptions referring to the elaboration of the design that this is practically unworkable.

In these stages, many architects base their estimates on data referring to unit prices per square metre gross floor area or cubic metre gross content of so-called reference projects, preferably from their own portfolios, since architects of course know these projects best.

4.6 Discussion and conclusions

4.6.1 Requirements for an estimating model

First of all, the environmental burden and, by consequence, eco-costs relate to all phases of the life-cycle of houses (and other products). So, as indicated in chapters 2 and 3, eco-cost estimating should have the scope of an LCC approach.

In order to fit in with the profession involved in housing projects, the applied technique in this respect should be the so-called operating estimate, in which e.g. maintenance and energy costs can be tuned to varying design specifications. Even in this type of estimates, investment and building costs form an important part of the costs to be taken into consideration from a quantitative point of view. On top of that, the building costs are most directly influenced by the design.

As concluded in the last section, many architects prefer to relate as to building cost data to their own experiences from previous design commissions concerning similar buildings. They do so, mainly because in the early process stages there is not a better alternative available.

Using these self-made cost data for the early process stages has several drawbacks:

- They are unable to communicate relevant eco-cost information, since the raw data on this subject are not readily available.
- The (greater part of) project documents in architectural firms are not structured in such a way that the contained cost data can be modelled according to the (main) dimensions of preliminary design.
- In general, the cost information from these reference projects is poorly connected to the information in later development stages.

In addition, very soon in the process, a need for more specified cost data will become evident (see Table 4.1). Design is probably dealing with alternative building forms and several combinations of functional and/or spatial entities may be considered. Technical specification of building elements, however, may be still far away. In this stage of preliminary design, information is needed that relates costs to alternative combinations of (functional) project sections and varying dimensions of buildings.

Not until the process stages of definite design and specifications, cost information referring to more specified elements (i.e. technical solutions) is required nor applicable, since the detailing of the design has not yet proceeded thus far. Only in these final stages, cost effects of applying different materials and semi-finished products are considered on a more extensive scale.

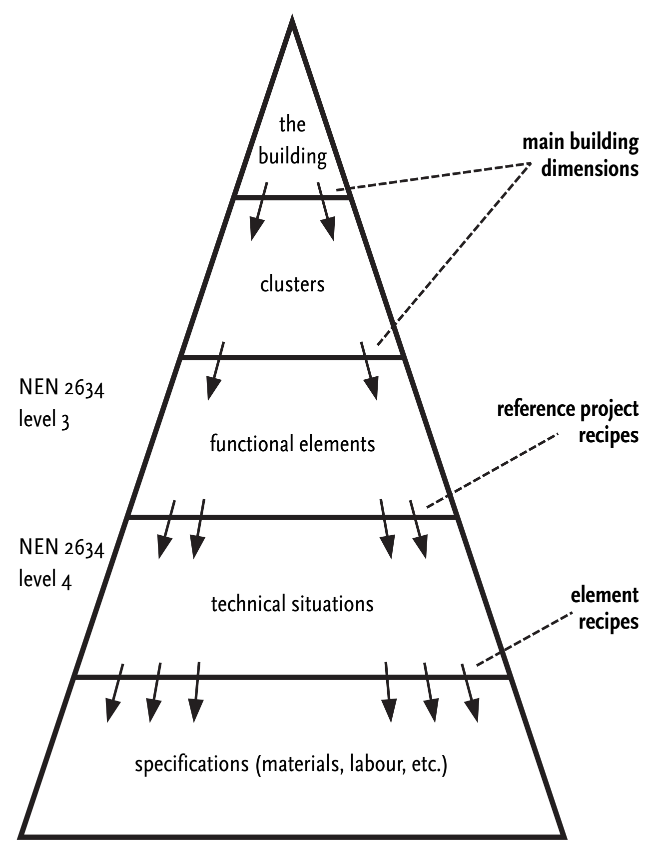
So, as also concluded by LISC (Section 4.2.4), cost analyses should be made in a way that they build on each other over the various stages of development.

At the same time, cost analyses should be closely related to the requirements from the design process. That means being specified if required, but global when the decisions involved have a global character; and, moreover, the model should be able to follow the designer 'up and down the design ladder', as described in Section 4.3.5.

4.6.2 Filling in the missing link

At this point the existing tools for cost estimating apparently have a missing link, as will be explained with the help of Figure 4.2. At the top end of the composition hierarchy, a general idea of building costs may be available,

Figure 4.2 Reference projects providing the missing link in the model of cost estimating based on elemental bills of quantites



based on square metre prices of previously designed projects. At the bottom end, unit-prices of technical solutions may be available from a data base of cost analyses, which links specified elements (i.e. technical solutions) to the costs of materials, labour etc. through element recipes.

In between, however, the existing estimating tools do not provide information about which combination of technical solutions is characteristic for the actual type of building in the concerned development project. To fill in this missing link, reference projects could provide the needed data, based on the idea that (within a building market region, e.g. the Netherlands) a building is a unique product, not so much because of the unique technical solutions it consists of, but much more because of the unique combination of (per se) similar technical solutions. To investigate the validity of this idea, detailed cost analyses have been made of 60 building projects, both residential (35) and non-residential (25) and both new construction (37) and renovation (23).

This investigation, which is reported separately (De Jonge, 2004), shows that building costs of executed projects can be reproduced by elemental bills of quantities and unit prices from a database of elements specified as technical solutions with standardised recipes of constructions, details and realisation methods. The accuracy of the estimates based on the elemental bills of quantities was plus or minus 6% compared to the actual (winning) tender prices, after all prices were indexed at January 2004.

In the cost analyses of the projects, the quantities of the applied technical solutions were assessed on two levels: first the quantities of the functional elements in the building project were established (on level 3 of NEN 2634), secondly the quantities of the technical solutions per unit of functional element were established (on level 4 of NEN 2634).

The quantities on level 3 are related to the main building dimensions. In building development projects (either new construction or renovation), these quantities can be established on the basis of design sketches, which are characteristic for development stages as early as the project definition and the beginning of the preliminary design.

The quantities on level 4 are largely related to the elaboration of the design that characteristically takes place during the transition from the preliminary design stage to the definite design stage. Here often the 'handwriting' of the architect comes in, as to the typical choice of materials, construction details etc. Here also the building type (a dwelling or for instance a church) and the 'looks' of a building (types of materials used for elevations or roofs) play a role.

In the early process stages, a building with a known set of quantities on level 4 can serve as a reference for a building cost estimate on level 3. If in that stage the architect (or the client) already has ideas about these elaborations on level 4, that differ considerably from these known set of quantities with respect to a certain element, he/she may adjust the quantities for that element to these ideas. This of course also adjusts the estimate in that respect (De Jonge, 2002c, 2003a, 2003b).

4.6.3 The Reference Projects Model

This section will focus on the structure of the estimating model that covers the traditional construction costs and the eco-costs in the production phase, as for its integration in the design and development process. This model is called the Reference Projects Model.

The outlines of the approach of cost estimating and eco-cost estimating in the operating and end of life stages by means of an operating estimate are described already in chapter 2 and 3. As far as these estimates consider the building or dwelling as a whole, they may well be executed in the process phases, in which the traditional operating costs usually are evaluated: in early feasibility studies and at the approval of the preliminary design. As far as architects or clients want to take life-cycle aspects of separate elements into consideration, they can of course do so any moment these elements are reviewed. Naturally, these moments can be expected to correspond with the design process in general.

The idea behind the Reference Projects Model is that an architect deduces the construction costs of a new design from the construction costs of a project he/she already knows: the reference project. Evidently, projects that contain the architect's own designed buildings are the reference projects most suitable to him/her. So, in general, an architect should relate the new project, in which he/she actually is involved as a designer, to other projects from his own portfolio. In estimating, two exceptions can be discerned on this rule:

- If the architect is confronted with a commission referring to a category of buildings he/she is not acquainted with.
- If there is not a database with well structured cost data referring to the architect's portfolio.

In these situations a public database of reference projects could provide 'second best' cost data for early development process stages. The Reference Projects Model is designed as such a database (Winket, 2004).

In the Reference Projects Model, the reference projects are presented in two forms: once in the form of a budget analysis based on the (specified) tender prices of an actually completed project. These so-called project analyses provide a survey of 'historical' construction costs (indexed to an up-to-date price level). Evidently, these project analyses contain all details and adjustments to the special situation in the analysed projects. Also market conditions at the day of tendering are reflected in the analyses.

However, construction costs of the reference projects are estimated as the elemental bills of quantities based on the analytical estimating model. These estimates are organised (according to NEN 2634) in a way that they can easily be adapted to the design sketches for new projects in varying stages of specification.

The estimates of the reference projects based on the analytical estimating model differ from the project analyses as for the fact that they are composed as elemental bills of quantities based on cost analyses of technical solutions with standardised specifications. These standardised specifications are composed in a way that they can serve as cost references for the effected building elements in various projects. In these bills of quantities, the constructions, details and realisation etc. are specified in a standardised way. Even the market conditions are 'controlled' by using fixed percentages for the calculation of overheads and profit (for the construction company).

By this approach from two separate starting points, the Reference Projects Model allows the architect to control the costs of his projects. On the one hand, the composition in the analytical estimating model gives the architect a firm grip while using the cost data in several scale levels throughout the design process. Since the elemental bills are based on technical solutions with standardised specifications, the architect knows were he stands. He knows the quality levels, details etc. that are corresponding with the cost data.

On the other hand, the project analyses may assure the architect of a footing of the cost data in real life practice.

By using the Reference Projects Model, architects (and clients) are able to estimate the costs of housing projects on an appropriate scale level in all stages of the development process.

From the point of view of the estimating technique, there is only one difference between traditional construction costs and eco-costs in the model: eco-costs cannot be verified on the basis of realised tender prices. The eco-cost data are implemented in the Reference Projects Model according to the principals that are described in Chapter 2.

4.6.4 Estimating tools for the Eco-costs/Value Ratio in housing projects

At this stage of research, it can be concluded, which combination of tools is available for the practical implementation of the EVR model in housing projects.

For calculations referring to the production phase and the end-of-life phase, the Reference Projects Model as described in the previous sections is operational. (However, some calibrating needs to precede the implementation in real-life projects.) For calculations referring to the operating phase the spreadsheet facility for Estimating Energy Demand (Section 2.6.5 and DGMR, 2004) and the Delft Maintenance Calculating Model (Section 2.6.6 and Appendix 4) can be combined and connected to the input interface of the Reference Projects Model. Some engineering is still needed to make this combination of tools for the operating phase available for architects in real-life projects.

Integration of the results of calculations with the described tools has to be conducted as will be shown in the next chapter.

5 The Eco-costs/Value Ratio of housing: two case studies

What can be expected from applying a tool based on the model of the Eco-costs/Value Ratio in terms of reducing the ecological burden of housing (in general and on project level)?

5.1 Introduction

In this chapter, two case studies are presented in order to illustrate the type of results that can be obtained by means of the developed models and tools.

First, the results of eco-cost calculations in 14 recently completed building projects are presented. The emphasis in these projects is on housing, i.e. new construction as well as renovation. However, some non-residential projects are added in order to get a preliminary indication of the position of the housing sector as related to other building categories.

Based on the results from these calculations, conclusions are drawn referring to the EVR of housing in the production phase.

Next, sustainability of housing is surveyed in terms of the EVR referring to the entire life cycle of houses. Based on an economic model of the investments and the operation of an apartment block, sustainability in housing is evaluated by comparing eco-costs and value of the apartment in varying scenarios.

5.2 Estimating costs and eco-costs in the production phase

5.2.1 Comparing recently completed projects

In order to investigate the range of the EVR in building projects with varying characteristics, the construction cost specifications of 14 building projects are compared. A practical problem in this context is that many stakeholders in development projects are rather reluctant to make project data available for cost research. Apart from their availability, the selection of the 14 building projects is based on the following criteria:

- new construction of various dwelling types, in order to investigate the distribution of EVR within the category of new construction;
- renovation of various dwelling types and types of intervention, in order to investigate the distribution of EVR within the category of renovation;
- both new construction and renovation, in order to investigate the difference (if any) between the EVR in both categories;
- new construction of non-residential buildings, in order to investigate a possible difference of EVR between residential and non-residential buildings.

Renovation of non-residential buildings is not included, because of the non-availability of data.

Table 5.1 Construction costs, eco-costs and EVR of 14 projects*)

General data per project and per dwelling (building)			Dwellings in project	m² UFA per dwelling (building)	m² GFA per dwelling (building)
1	new construction	warehouse		685	775
2	new construction	office 'luxurious'		585	772
3	new construction	office 'standard'		336	398
4	new construction	detached house N	1	257	430
5	new construction	detached house Z	1	142	174
6	new construction	terraced town houses 'small'	29	117	135
7	new construction	terraced town houses 'large'	15	144	171
8	new construction	conservatory houses	16	145	193
9	new construction	apartments	18	73	89
10	refurbisment skin	terraced houses	46	89	150
11	refurbisment interior	terraced houses	54	110	168
12	refurbishment + lift	staircase access flats	24	74	107
13	refurbishment + lift	tower block flats	24	58	90
14	extensive renovation + lift	tower block flats	31	83	127

Construction costs and eco-costs per dwelling (building)			Construction costs indexed tender	Construction costs reflex estimate	Eco costs reflex estimate	EVR in %
1	new construction	warehouse	400,311	452,708	238,663	53
2	new construction	office 'luxurious'	750,782	742,546	257,284	35
3	new construction	office 'standard'	383,863	385,019	150,959	39
4	new construction	detached house N	456,329	415,614	157,522	38
5	new construction	detached house Z	259,274	263,486	87,902	33
6	new construction	terraced town houses 'small'	86,726	89,599	39,653	44
7	new construction	terraced town houses 'large'	138,682	136,754	58,649	43
8	new construction	conservatory houses	144,281	154,368	63,377	41
9	new construction	apartments	77,063	80,125	30,821	38
10	refurbisment skin	terraced houses	28,605	30,227	6,000	20
11	refurbisment interior	terraced houses	13,211	14,148	2,135	15
12	refurbishment + lift	staircase access flats	49,448	51,413	12,603	25
13	refurbishment + lift	tower block flats	34,369	33,951	8,406	25
14	extensive renovation + lift	tower block flats	81,445	84,012	19,000	23

The survey of construction costs, i.e. both traditional costs and eco-costs, of the selected projects is based on the following data:

- Analysing the winning tenders of the projects has resulted in cost surveys according to NEN 2634 (all prices indexed at January 2004).
- So-called ‘reflex estimates’ of the construction costs of all projects are composed. Reflex estimates are elemental bills of quantities that represent the

Construction costs and eco-costs per m² GFA			Construction costs indexed tender	Construction costs reflex estimate	Eco costs reflex estimate	EVR in %
1	new construction	warehouse	517	584	308	53
2	new construction	office 'luxurious'	973	962	333	35
3	new construction	office 'standard'	963	966	379	39
4	new construction	detached house N	1,061	967	366	38
5	new construction	detached house Z	1,491	1,516	506	33
6	new construction	terraced town houses 'small'	641	662	293	44
7	new construction	terraced town houses 'large'	810	799	343	43
8	new construction	conservatory houses	747	799	328	41
9	new construction	apartments	863	897	345	38
10	refurbisment skin	terraced houses	191	202	40	20
11	refurbisment interior	terraced houses	79	84	13	15
12	refurbishment + lift	staircase access flats	462	480	118	25
13	refurbishment + lift	tower block flats	383	378	94	25
14	extensive renovation + lift	tower block flats	644	664	150	23

Construction costs and eco-costs per m² UFA			Construction costs indexed tender	Construction costs reflex estimate	Eco costs reflex estimate	EVR in %
1	new construction	warehouse	584	661	348	53
2	new construction	office 'luxurious'	1,283	1,269	440	35
3	new construction	office 'standard'	1,143	1,146	449	39
4	new construction	detached house N	1,776	1,617	613	38
5	new construction	detached house Z	1,832	1,862	621	33
6	new construction	terraced town houses 'small'	740	765	338	44
7	new construction	terraced town houses 'large'	962	949	407	43
8	new construction	conservatory houses	992	1,062	436	41
9	new construction	apartments	1,060	1,103	424	38
10	refurbisment skin	terraced houses	320	338	67	20
11	refurbisment interior	terraced houses	121	129	19	15
12	refurbishment + lift	staircase access flats	672	698	171	25
13	refurbishment + lift	tower block flats	598	590	146	25
14	extensive renovation + lift	tower block flats	985	1,016	230	23

**) All costs in euros, VAT excluded, price level January 2004.*

analysed tenders. The specifications in these estimates are accurately related to the investigated projects as for construction methods and applied materials. However, the recipes and unit prices of the elements in these reflex estimates are based on the Winket construction cost database (Winket, 2004).

- The reflex estimates, being the traditional costs estimates of the investiga-

Warehouse at Roosendaal (new construction).

ted projects, are transformed into eco-cost estimates, as described in Section 2.6.3.

- Finally, EVR on construction costs level of all projects are computed by dividing the eco-costs by the construction costs (as calculated in the reflex estimates).
- All cost figures are presented per dwelling (building), per square metre GFA ('bruto vloeroppervlakte') and per square metre UFA ('gebruiksoppervlakte') according to NEN Standard 2580 (NEN, 1997).

5.2.2 Traditional costs and eco-costs of construction

The costs per dwelling in the new construction projects vary because of varying housing types, sizes, construction methods and materials (Gerritse, 1999). However, this variety of costs is beyond the scope of this study.

The costs per dwelling in the renovation projects also vary because of housing types, sizes, construction methods and materials. Moreover, renovation projects vary in respect of the extensity of the intervention:

- in project 10, 'refurbishment skin' comprises improvement of the elevations, i.e. (partial) renewal of the brickwork skin and the windows, and renewal of services and finishes in kitchens and bathrooms;
- in project 11, 'refurbishment interior' only comprises renewing services and finishes in kitchens and bathrooms;
- in project 12, 'refurbishment + lift' comprises cleaning the brickwork skin, (retrofitting) skin insulation, renewing windows and roof finishes, services and finishes in kitchens and bathrooms, addition of lifts with required structural works, which in this case are completely new additional building sections in the front of the blocks;
- in project 13, 'refurbishment + lift' comprises external wall insulation, rene-

Small 'luxurious' office building at Zevenbergen (new construction).

wing windows and roof finishes, extending balconies, renewing services and finishes in kitchens and bathrooms, replacing lifts with required adjustment of structural works;
- in project 14, 'renovation + lift' comprises external wall insulation, renewing windows and roof finishes, extending balconies, replacing lifts with required adjustment of structural works. This renovation also comprises a complete interior redevelopment, resulting in up-to-date new apartments in an adjusted lay-out with new differentiation of housing. This approach is also referred to as extensive renovation.

In Table 5.1, the traditional construction costs, as estimated by means of the reflex estimates, are between 91% and 113% as compared to the (indexed) bidding prices. The standard deviation of the outcomes of the reflex estimates as compared to the observed bidding prices is 5.62%. Taking into account the varying market conditions of the researched projects, this can be considered quite accurate. Compared to accuracy in eco-cost calculations, this deviation magnitude certainly is acceptable (Vogtländer, 2001, p. 38).

5.2.3 EVR on construction cost level

New construction of houses and offices (in Table 5.1) show EVR on similar levels:
- EVR of houses is on average 39% (median) to 42% (weighted);
- EVR of offices is on average 37% (median) to 36% (weighted).

The EVR of the warehouse (53%) is significantly higher than the EVR of the houses and offices.

Note that in this study no research has been done concerning other investments than construction costs. What is or is not covered by construction cost estimates in different building branches may depend largely on varying conventions. In health care projects for instance, finishes and fittings are usually assigned to construction costs, while in housing projects in the Netherlands these costs are assigned to furnishing expenses. In office building projects and utility projects like warehouses, the assignment of cost items to either construction costs or furnishing expenses may differ from project tot project. So, based on this study, it cannot be fully established if differences or similarities of the outcomes in various building branches, other than housing, are real or seeming (De Jonge, 2000, 2002d and 2003c).

Renovation shows significantly lower EVR than new construction:
- EVR of new construction of houses is on average – 39% (median) and 42% (weighted);
- EVR of renovation of houses is on average – 23% (median) and 22% (weighted).

The investigated projects do not show significant deviation between the EVR of refurbishment and extensive renovation. However, the refurbishment projects that are less extensive (in terms of spent money per square metre UFA) show lower EVR, 15% and 20%, than the refurbishment projects that are more extensive. These last projects (nr. 12 and 13) show EVR of 25%.

5.2.4 Causes of varying EVR

Studying the EVR in the different categories more closely, provides information about the origin of the differences. Table 5.2 shows the distribution of construction costs and eco-costs over clusters of elements in the various building categories.

The table shows that the major part of the EVR in new construction projects is caused by eco-costs related to the construction of the Substructure, the Structure and the Skin of the buildings. In renovation projects, the EVR is largely caused by eco-costs related to the Skin, the Space plan and the Services.

Comparing the distribution of eco-costs to the distribution of traditional construction costs in the various categories shows that in new construction, the share of the Substructure and Structure in the eco-costs is relatively high as compared to the share of these building parts in the traditional construction costs. The Skin of houses forms an important part of both traditional construction costs and eco-costs, in new construction as well as in renovation projects.

This indicates that constructions and materials, which are applied in the Substructure, Structure and Skin of buildings, may have relatively high eco-costs. And that these relatively high eco-costs cause the relatively high EVR of new construction as compared to renovation.

Table 5.2 Distribution of traditional costs and eco-costs of construction in %

	Warehouse (new construction)			Offices (new construction)		
	distribution of construction costs	distribution of (construction) eco-costs	EVR	distribution of construction costs	distribution of (construction) eco-costs	EVR
Substructrure (foundation, ground floor slab)	21	50	27	5	14	5
Structure (load bearing elements)	13	7	4	18	34	12
Skin (roofs, elevations)	16	18	10	30	23	8
Space plan (separations, floor finishes, stairs, ceilings)	12	6	3	15	11	4
Services (mechanical, electrical, lift)	11	4	2	9	5	2
Sanitary facilities (bathrooms, kitchens)	1	0	0	1	1	0
Sundries (site facilities, construction management, overheads)	26	13	7	22	12	4
	100	100	53	100	100	36

	Houses (new construction)			Houses (renovation)		
	distribution of construction costs	distribution of (construction) eco-costs	EVR	distribution of construction costs	distribution of (construction) eco-costs	EVR
Substructrure (foundation, ground floor slab)	7	15	6	1	3	1
Structure (load bearing elements)	19	37	15	1	2	0
Skin (roofs, elevations)	30	28	12	33	40	9
Space plan (separations, floor finishes, stairs, ceilings)	12	8	3	19	19	4
Services (mechanical, electrical, lift)	10	5	2	19	19	4
Sanitary facilities (bathrooms, kitchens)	3	1	0	6	4	1
Sundries (site facilities, construction management, overheads)	19	6	3	21	14	3
	100	100	42	100	100	22

Note that all EVR figures in this table are related to the value as represented by the total amount of construction costs of the building. E.g. the EVR of the 'Skin of Houses (new construction)' is indicated as 12. This means that out of the 42% EVR of 'Houses (new construction)' 12% is designated to the 'Skin'.

5.2.5 Possible improvements

As explained in Section 2.6.3, the environmental burden (the eco-costs) of a building in the production phase can be considered as consisting of the eco-costs of building materials (semi-finished products) plus the eco-costs of the assembling activities. So, in order to find ways to reduce the eco-costs of houses in the production phase the emphasis should be on building materials.

As to building materials there are two principles for improving the environmental characteristics of a building: reducing the environmental burden by alterations in the production of the affected materials, or applying alternative materials, which have a lower impact on the environment.

Materials

In the researched projects, almost half of the eco-costs are related to three types of products: concrete structures and products (floor slabs, foundation beams, foundation piles, pavement etc.), meranti (tropical wood, mainly applied in window frames and doors) and aluminium (window frames).

Changing production aspects

The major part of the eco-costs of concrete, 93% according to the data used in this study, is assigned to the pollution class 'winter smog', caused by fine dust. Regarding this fine dust problem of concrete, two questions are relevant:

- is fine dust as produced by the cement industry indeed inducing 'winter smog' in the same way as smoke from diesel engines or from fireplaces and coal stoves?
- have dust reducing measures, taken by the cement industry in 2002 (ENCI, 2002), already reduced the 'winter smog' pollution and (if so) has that reduction been included in the eco-cost figures related to concrete products?

The major part of the eco-costs of meranti, 94% according to the data used in this study, is assigned to the materials depletion factor representing the extinction of tropical rain forest due to uncontrolled large scale felling of trees. Using meranti, which is produced e.g. according to FSC-trademark conditions, could considerably improve this sustainability aspect.

The major parts of the eco-costs of aluminium are assigned to the pollution classes 'greenhouse effect' and 'acidification' and to the 'depletion' of raw material (bauxite). According to the data used in this study: 34%, 20%, 34% respectively. Using recycled aluminium could reduce the eco-costs of aluminium by approximately 85%.

Reducing the eco-costs of the mentioned materials and products could bring considerable reduction of the environmental burden of building construction.

Halving the EVR of concrete products would bring back e.g. the EVR of the investigated warehouse from 53% to 28%, and the EVR of the 'small' terraced houses from 44% to 36%. Halving the EVR of tropical wood products would bring back e.g. the EVR of the 'small' terraced houses from 44% to 40% and the EVR of the refurbishment of skin project from 20% to 17%.

Alternative products

The application of concrete in foundations of buildings seems hard to avoid. In the construction of walls, however, concrete can easily be substituted by sand-lime building blocks in many housing projects. According to the data used in this study, this reduces the EVR from 177% to 40% compared to the costs of the wall as a building element. Since the construction costs of concrete walls and sand-lime walls are on the same level, switching to sand-lime blocks can be a sensible decision, provided that there are no objections from the structural point of view or in respect of other required qualities.

From a technical point of view, concrete floors in a housing project could be substituted by constructions based on wood. For instance, the floors could be constructed of plywood on wooden beams completed with freely suspended plasterboard ceilings with rock-wool filling. In many cases, however, the reduction of the eco-costs would be exceeded by the increase of the construction costs due to the application of these wooden floors. A choice for such alternative constructions cannot be qualified to be cost-effective. According to the definition of eco-costs (Section 2.6.1) apparently, other measures – outside the building project – can provide the required reduction of ecological burden in a less expensive way.

As an alternative material for meranti or aluminium in window frames, pine could be considered. Pine window frames, however, are usually assessed at a lower value by the customers because of their alleged inferior durability. This last observation illustrates the interconnection of the various life-cycle stages in the decision-making process concerning sustainability. Durability is related to the operating phase of housing, in which costs of maintenance and repair play important roles.

5.3 Applying the EVR model at housing stock intervention projects

5.3.1 Introduction to a case

As discussed in the previous chapters, the EVR of housing should be considered, not just at construction costs level, but also at the levels of investment and operation. In this section, calculations are presented in order to investi-

The refurbishment and renovation project of the Tolhuis-flats at Nijmegen is used as a model for this case study.

gate in which direction and to what extent improvements of ecological sustainability can be expected by alterations in the approach of stock management in the housing sector.

Based on practical experience in several redevelopment and renovation projects, the following case has been constructed. A group of apartment blocks, built in the 1960s, contains approximately 200 apartments. In the course of time, the customer value of the apartments has been reduced to such a low level (see sections 3.4.3 and 3.5.2) that vacancies are well above average, compared to the rental stock in the regional housing market. In fact, the apartments have become very unpopular. In general however, the neighbourhood is fairly attractive. So, prospects for new developments are quite good.

The landlord, a Dutch housing association, is planning to start an intervention project. The characteristic approach of such a project would be to execute a feasibility study concerning various options in order to support a final project definition. The figures in this case study refer to one of the blocks. This block contains 50 apartments.

5.3.2 Discerned interventions

In principle, five strategies – i.e. five types of interventions – are possible for existing apartment blocks: unchanged continued operation, selling the apartments, refurbishment aimed at improving one or more quality dimensions of the apartments as they are, extensive renovation aimed at creating (virtually) new apartments within the structure of the existing block and, finally, redevelopment aimed at the construction of completely new houses.

The project '37 apartments in Venray' is used as a model for the strategy of new construction in this case study.

Continued operation or selling

Any feasibility study should start with analyzing the result of an unchanged continuation of the existing situation. So, first of all, the economic consequences of continued operation are mapped out.

The value of the existing property is estimated at €24,716 per apartment. This value is the equivalent of the indirect yield value of continued operation for a term of 15 years, followed by disposal aimed at demolition and redevelopment of the site.

In view of the unpopularity of the apartments hardly any demand can be expected if the apartments are put up for sale. Especially, because of the large number of the apartments the expected proceeds will hardly exceed the before-mentioned indirect yield value. Moreover, the landlord does not consider selling these unwanted flats in line with its objectives as a housing association. Therefore, the possibility of selling will not be taken into consideration in the rest of this study.

Refurbishment

In case of refurbishment, improvements of the apartments are executed without major changes in the existing lay-out. In this case, refurbishment consists of replacing windows and external doors, thermal insulation of elevations, adjusting roof covering and edges, enlarging balconies, improving kitchens, adjusting electrical and mechanical systems, and major repair of common areas.

Extensive renovation

Extensive renovation is an intervention that is considered to improve the building to a level that is similar to new construction. Maybe some quality

Table 5.3 Traditional costs and eco-costs per apartment on investment level

			Traditional costs		Eco-costs	EVR
			per unit	total		in %
Continued operation	50	units				
Land/existing property	98.86	m²	250	24,716	-	0
Demolition costs	-	units	5,000	-	-	0
Construction costs (Cc)	57.00	m²	-	-	-	0
Additional costs	15%	of Cc		-	-	0
Investment cost				24,716	-	0
Refurbishment	50	units				
Land/existing property	98.86	m²	250	24,716	-	0
Demolition costs	-	units	5,000	-	-	0
Construction costs (Cc)	57.00	m²	711	40,514	10,005	25
Additional costs	15%	of Cc		6,077	851	14
Investment cost				71,307	10,856	15
Extensive renovation	30	units				
Land/existing property	164.77	m²	250	41,193	-	0
Demolition costs	-	units	5,000	-	-	0
Construction costs (Cc)	83.,00	m²	1,249	103,688	25,007	24
Additional costs	15%	of Cc		15,553	2,177	14
Investment cost				160,435	27,184	17
New construction	37	units				
Land/existing property	133.60	m²	250	33,400	-	0
Demolition costs	1.35	units	5,000	6,757	2,365	35
Construction costs (Cc)	102.00	m²	1,268	129,322	64,301	50
Additional costs	15%	of Cc		19,398	2,716	14
Investment cost				188,877	69,382	37

dimensions are slightly inferior, but other dimensions may even be better than can be obtained by new construction.

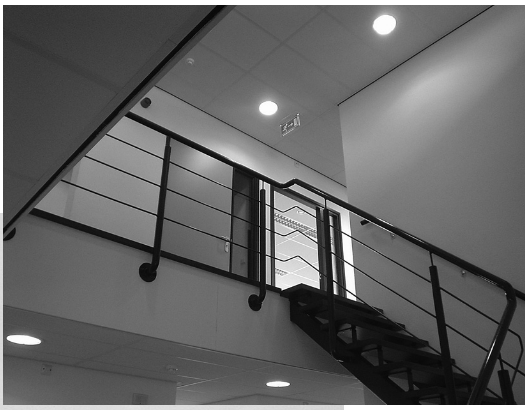
In practice, the feasibility of extensive renovation is related to the possibilities for changes in the lay-out offered by the existing structure of the apartment block (Andeweg-van Battum, 2002).

Usually, these changes in the lay-out are intended to enlarge the apartments produced by the extensive renovation. After the intervention, the block will contain a reduced number of bigger apartments.

In the case study, the extensive renovation consists of the same interventions as the refurbishment and, on top of that, the lay-out of the flats will be changed completely. Of course, all fitting and finishing will also be replaced.

New construction

This strategy can achieve qualities that are beyond the possibilities of renovation. For instance, the lay-out of the site can be rearranged and car parking



'Standard' office building at Etten-Leur (new construction).

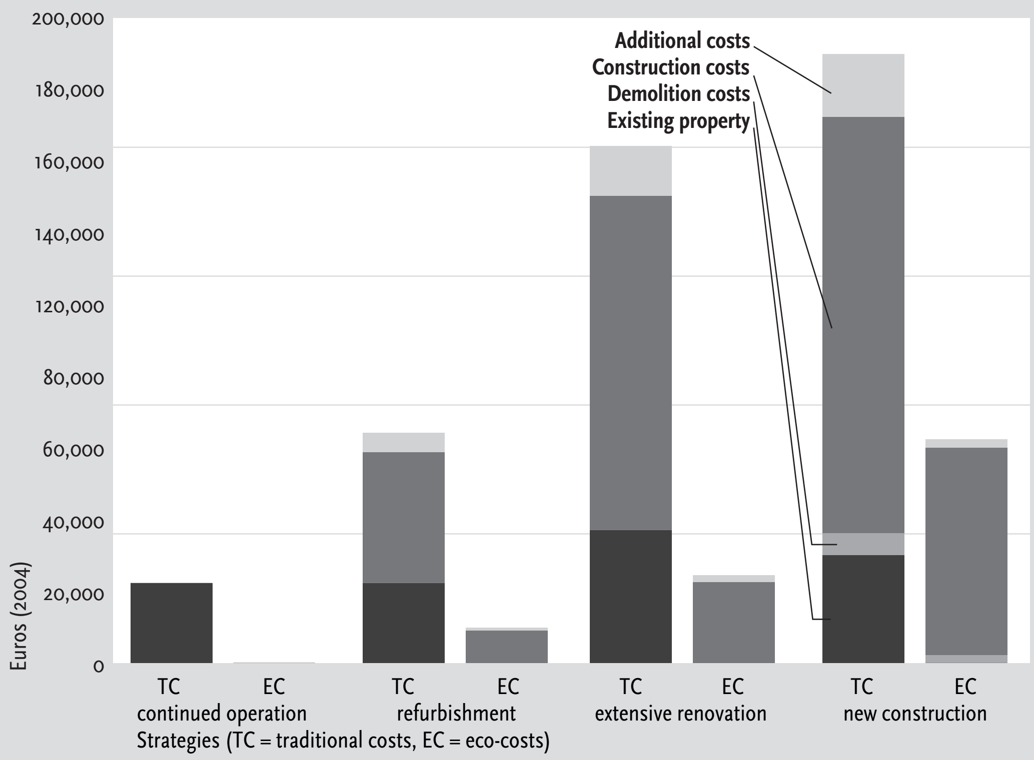
can be accommodated in the basement of a new apartment building. As a model for this strategy an apartment building in Venray is used.

5.3.3 Calculations concerning investments

Table 5.3 surveys both traditional costs and eco-costs on investment level per apartment after the inverventions that belong to the discerned strategies.

As mentioned, the value of the existing apartments is estimated at €24,716 per unit before any intervention. This value is contributed to the – new or renewed – apartments, which result after the various interventions. Obviously, if an intervention produces a larger number of new apartments, the portion per apartment of these costs is smaller, and vice versa. In the case study the value of the existing apartments, as contributed to the new apartments, varies from €24,716 to €41,193 per new apartment. The existing apartments as such are not accompanied by eco-costs in the investment-cost calculation. The demolition costs of the existing apartments, estimated at €5,000 per (demolished) unit, are obviously existent in the case of new construction only. Refurbishment, extensive renovation and new construction all bring their characteristic construction costs and additional costs. Both the analyses of the traditional costs and eco-costs of construction can be seen in Appendix 6. The eco-costs of construction are estimated according to Chapter 2. The

Figure 5.1 Traditional costs and eco-costs of investments at several strategies



results of all these traditional and eco-cost calculations are inserted in Table 5.3. In the traditional economic sense, the additional costs are estimated at 15% of the construction costs. Since the additional costs mainly concern office activities, their eco-costs are estimated by applying an EVR of 14% (Vogtländer, 2001, p. 33 and Appendix 2).

The final results of the investment calculations in Table 5.3 are presented in Figure 5.1 as traditional costs and eco-costs per apartment after the interventions.

The rearranged apartments of the extensive renovation strategy have approximately 1.5 times the sizes of the original ones. The newly-constructed apartments are even larger and are provided with a basement car park. In case of new construction, the housing density is reduced. However, extensive renovation is often resulting in even less density. In order to avoid this, adding an extra floor on top of the existing building could be considered. Of course, new construction can also consist of more floors than the present buildings. It is questionable, however, whether that approach would provide the required housing quality.

On investment level, the EVR of new construction clearly is the highest. Moreover, also in real figures, the all-in construction costs and eco-costs per apartment are the highest in new construction.

5.3.4 Traditional costs and eco-costs on operating level

In real-life projects, the investments of the discerned strategies are compared to the expected revenues of the according operations in terms of traditional economic figures. Strategies, which are expected to be clearly less profitable (as compared to the possibilities related to the intended target-group), are usually abandoned. In this case study, all strategies – except for selling – are assumed to result in a more or less break-even operation (in the context of providing housing facilities for different target-groups). This assumption allows us to investigate the results of eco-cost estimating for all the strategies.

In table 5.4a, the input parameters for the discounted cash flow (DCF) calculations of the various operating results are presented. Table 5.4b shows the calculated net present values (NPV), also called the indirect yield values, of the operations.

The rent in the calculations is set at a level just sufficient for a break-even operation at the assumed discount rate (expressed as a real interest rate). As shown in table 5.4a, the rent is reduced during the operating term according to the development of the customer quality, as discussed in chapter 3. Also the length of the operating terms and the residual value at the end of the operating terms are supposed to be in line with that approach.

After an intervention, the new rent is supposed to be established according to the customer quality. After an intervention like that, tenants probably will assess the total value of the various quality dimensions on a steady level for a couple of years. A house needs some time to 'settle itself': the garden has to mature, furniture and stuff should find a suitable place, fittings and facilities have to be tuned etc. In the rental trend of the model, this is translated by a period of 5 years, in which the (real value of the) rent remains equal. After that period a yearly reduction of -1.8% is applied in order to get the 65% rent level at the end of a 30 years operating term as mentioned in chapter 3.

As for the Net Present Value of the rental yield, the results of this approach show little differences with the assumptions in operating estimates as usually made by housing associations in the Netherlands. The actual difference between the new approach and the traditional one mainly concerns the value development and the assessment of the risks in the long term. (See also Figures 3.3 and 3.4.)

The vacancy rate and the operating expenses are set at common levels for Dutch housing associations (CFV, 2003). The yearly operating expenses are adjusted to the varying sizes and types of the apartments: partly the expenses are computed as a fixed amount of money per dwelling (e.g. management is considered that way), partly they are related to the quantities of building features like roofs, elevations, balconies, stairs and mechanical and electrical services. A general revision of services halfway the 30-years operating term is

Table 5.4a Parameters for Discouted Cash Flow calculations of traditional costs and eco-costs per apartment

	Traditional costs	Eco-costs	EVR		
				Operating term (years)	15
Continued operation				inflation rate	0.0%
Monthly rent (1st year)	228	32	14%	rent increase (until year 6)	0.0%
Monthly rent (15th year)	177	25	14%	rental trend (starting year 6)	-1.8%
Monthly rent (30th year)	-	-	14%	vacancy rate	10.0%
Operating expenses (yearly)	1,253	313	25%	discount rate	3.0%
Residual value	19,716	-	0%	initial land costs	24,716
				Operating term (years)	30
Refurbishment				inflation rate	0.0%
Monthly rent (1st year)	446	89	20%	rent increase (until year 6)	0.0%
Monthly rent (15th year)	346	69	20%	rental trend (starting year 6)	-1.8%
Monthly rent (30th year)	263	52	20%	vacancy rate	2.0%
Operating expenses (yearly)	1,253	313	25%	discount rate	3.0%
Residual value	24,716	-	0%	initial land costs	24,716
				Operating term (years)	30
Extensive renovation				inflation rate	0.0%
Monthly rent (1st year)	845	170	20%	rent increase (until year 6)	0.0%
Monthly rent (15th year)	655	132	20%	rental trend (starting year 6)	-1.8%
Monthly rent (30th year)	499	100	20%	vacancy rate	2.0%
Operating expenses (yearly)	1,417	354	25%	discount rate	3.0%
Residual value	60,965	3,350	5%	initial land costs	41,193
				Operating term (years)	30
New construction				inflation rate	0.0%
Monthly rent (1st year)	983	368	37%	rent increase (until year 6)	0.0%
Monthly rent (15th year)	762	286	37%	rental trend (starting year 6)	-1.8%
Monthly rent (30th year)	581	217	37%	vacancy rate	2.0%
Operating expenses (yearly)	1,554	389	25%	discount rate	3.0%
Residual value	71,773	14,096	20%	initial land costs	33,400

assumed to be included in the yearly reservations for maintenance.

The allocation of eco-costs takes place in line with economic principles (everything based on the Present Value). This includes that the eco-costs of the indirect yield value (i.e. the present value of the operation) equal the eco-costs of the investment.

In table 5.4a, the eco-costs of the (yearly) operating expenses are estimated by means of an EVR counting 25%, being a weighted average of the EVR of the usual maintenance and management activities: paintwork repair and renewal, glazing and (bituminous) roof covering for maintenance and 'office work'

Table 5.4b Traditional costs and eco-costs on operating level per apartment

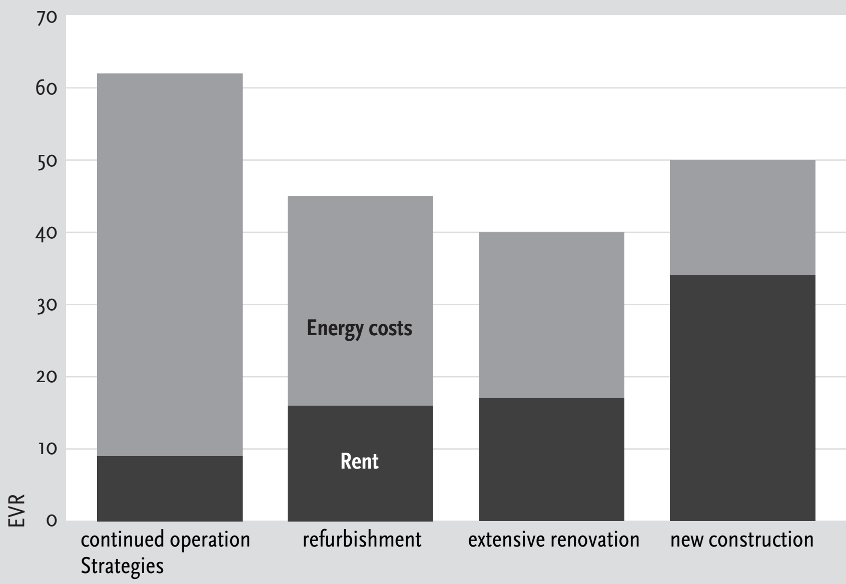
	Traditional costs	Eco-costs	EVR
Continued operation			
Present value of rent	27,468	3,852	14%
Present value of risidual value	12,655	-	0%
Present value of operating expenses	-/- 15,407	-/- 3,852	25%
Indirect yield value	24,716	-	0%
Refurbishment			
Present value of rent	86,421	17,180	20%
Present value of risidual value	10,183	-	0%
Present value of operating expenses	-/- 25,296	-/- 6,324	25%
Indirect yield value	71,307	10,856	15%
Extensive renovation			
Present value of rent	163,925	32,956	20%
Present value of risidual value	25,117	1,380	5%
Present value of operating expenses	-/- 28,607	-/- 7,152	25%
Indirect yield value	160,435	27,184	17%
New construction			
Present value of rent	190,680	71,417	37%
Present value of risidual value	29,570	5,807	20%
Present value of operating expenses	-/- 31,373	-/- 7,843	25%
Indirect yield value	188,877	69,382	37%

(Vogtländer, 2001 p. 33) for management. In table 5.4b, also the traditional costs and eco-costs of operating expenses are discounted to present value.

In the operating estimates in table 5.4b, the present value of the rent plus the present value of the residual value minus the present value of the operating expenses equals the indirect yield value, which in its turn equals the investment costs. This is true for both traditional costs and eco-costs.

The total amount of the eco-costs of the investment minus the present value of the eco-costs of the operating expenses is assigned proportionally to (the present value of) the rent and residual value (minus the land costs part).

Figure 5.2 Eco-costs/Value Ratio of housing expenses at several strategies



The land costs part of the residual value is not charged with eco-costs in order to assign all eco-costs to the building during the time it is in use. So, the total eco-costs of operation are distributed pro rata to the present value of the rent and the present value of the buildings remaining at the end of the operating term.

The residual value at the end of the operating term is transferred to the next operating term. It takes its 'fair' share of eco-costs. This lowers the eco-costs of the first operating term. That is important for evaluating cases in which stakeholders want to make ecologically sound long-term investments. E.g. the effectiveness of IFD ('Industrial Flexible Demountable') projects could be evaluated this way. In these IFD projects, special constructive facilities may raise the eco-costs of the actual investment in order to diminish the eco-costs of future investments. The indicated method of settlement provides a possibility to assess whether the proposed facilities are useful or not.

The results of the operating estimates, as presented in table 5.4b, show that the EVR of the (cost price) rent is the highest in case of new construction and the lowest in case of continued operation.

5.3.5 Traditional costs and eco-costs of housing

Finally, the results of the operating estimates are transferred to a survey of housing expenses (for the account of the tenant), as shown in table 5.5.

Apart from rent, housing expenses also consist of energy costs. The levels of energy costs following the varying interventions are assessed with help of the energy demand estimating tool as described in chapter 2.

Table 5.5 shows that – in the traditional economic sense – the increase of housing expenses following refurbishment is relatively moderate compared

Table 5.5 Traditional costs and eco-costs of housing per apartment

	Traditional costs	Eco-costs	EVR
Continued operation			
Monthly rent (1st year)	228	32	14%
Monthly rent (15th year)	177	25	14%
Monthly rent (30th year)	-	-	-
Monthly energy costs	90	142	158%
Monthly housing expenses (1st year)	318	174	55%
Monthly housing expenses (15th year)	267	167	63%
Monthly housing expenses (30th year)	-	-	-
Refurbishment			
Monthly rent (1st year)	446	89	20%
Monthly rent (15th year)	346	69	20%
Monthly rent (30th year)	263	52	20%
Monthly energy costs	77	122	158%
Monthly housing expenses (1st year)	523	210	40%
Monthly housing expenses (15th year)	423	190	45%
Monthly housing expenses (30th year)	340	174	51%
Extensive renovation			
Monthly rent (1st year)	845	170	20%
Monthly rent (15th year)	655	132	20%
Monthly rent (30th year)	499	100	20%
Monthly energy costs	111	175	158%
Monthly housing expenses (1st year)	956	345	36%
Monthly housing expenses (15th year)	766	307	40%
Monthly housing expenses (30th year)	610	275	45%
New construction			
Monthly rent (1st year)	983	368	37%
Monthly rent (15th year)	762	286	37%
Monthly rent (30th year)	581	217	37%
Monthly energy costs	88	139	158%
Monthly housing expenses (1st year)	1,071	507	47%
Monthly housing expenses (15th year)	850	424	50%
Monthly housing expenses (30th year)	668	356	53%

to the present housing expenses (in the table presented as expenses of continued operation). The increase of the rent is somewhat compensated by a decrease of the energy costs.

The apartments that result from the extensive renovation have considerably higher rents. However, they have usable floor areas of 83 m^2 versus 57 m^2 per flat as existent and after refurbishment. The energy demand of the extensively renovated apartments corresponds with their larger usable floor area.

The rent of the newly-constructed flats exceeds the rent of the renovated apartments. The energy demand per apartment, however, turns out to be lower. In view of the provided qualities, the overall housing expenses of new construction seem to be rather agreeable in comparison with the housing expenses of renovation.

In a real-life feasibility study, the final evaluation of the various strategies could take place by comparing the results of the estimates with the findings of a customer value assessment, according to chapter 3. In this case study, however, all strategies are assumed to result in acceptable levels of housing expenses (for different target groups), in the traditional economic sense.

In other words: the housing expenses of the varying apartments can be considered to represent the values of the provided housing services. So, in line with the model of the Eco-costs/Value Ratio (EVR), the environmental burden of the discerned strategies for interventions in the housing stock can be compared with their value by comparing them with the (traditional economic) housing expenses.

The EVR of refurbishment calculated this way, turns out to be lower than the EVR of an unchanged continued operation. As can be seen in Figure 5.2, extensive renovation has an EVR that is even lower than that. The EVR of new construction turns out to be lower than the EVR of continued operation, but it is higher than the EVR of renovation.

Figure 5.2 shows, which part of the EVR is due to the rent and which part to the energy costs. As can be seen in Table 5.5, the energy demand in refurbished and renovated apartments tends to be higher than the demand in newly-constructed ones (per square metre of useable floor area).

In the cases of refurbishment and renovation, a relatively larger part of the expenses consists of energy costs than in the case of new construction. These energy costs raise the Eco-costs/Value Ratios of refurbishment and renovation. However, they remain clearly below the EVR of new construction.

6 Conclusions and evaluation

Is estimating eco-costs and weighing them against intended value, on project level, a useful way of evaluating ex ante the ecological impact of (alternative) plans for interventions in the housing stock, in particular in the early stages of development processes?

6.1 Reflection on the problem

In this chapter, the problem of how to evaluate the ecological impact of possible interventions in the housing stock is reconsidered following the research questions in Section 1.6. Finally, some remarks are devoted to the context, in which the elaborated model of the Eco-costs/Value Ratio for Housing Projects can be used.

6.2 Conclusions

6.2.1 Eco-costs

What is understood by 'eco-costs' and what is a practical way of estimating eco-costs for new building design and renovation plans?

According to the definition in Section 2.6.1, the eco-costs of a housing project, whether or not refurbished, renovated or newly-constructed, indicate the amount of costs that should be involved in the prevention of the environmental problems, pollution and resource depletion, caused by the project. The eco-costs, however, are virtual costs, because the indicated prevention measures are not taken in the real-life situation.

The eco-costs in the EVR model do not indicate how serious a specific pollution or depletion is for society, compared to the environmental burden by other materials, services or products. They indicate what budget should be reserved for measures, outside the project, to balance the project with 'earth's carrying capacity'. That is: if the project does not comply with the 'best practice' norm for sustainability (as described in Section 2.6.1), how much money would be needed to improve the ecological performance of one or more other products in order to compensate for the lack of compliance in this project?

This definition of eco-costs can serve very well to evaluate whether a certain alteration in the plans, aimed at reducing ecological burden, is cost-effective or not. If the extra costs involved in the alteration remain lower than the difference in eco-costs, the alteration can be considered to be a relatively cost-effective measure to reduce ecological burden. If the extra costs exceed the difference in eco-costs, a pollution prevention measure elsewhere in the production chain is preferable.

In formula:
If $\partial C > \partial E$, project alteration is not cost-effective

In which ∂C = extra costs involved in the alteration of the project
∂E = reduction of eco-costs related to the alteration of the project

By connecting an eco-cost database to an estimating system (any estimating system) that is used in the development process of the housing project to estimate traditional construction costs, eco-costs can be estimated virtually without burdening the process with extra calculation activities. A precondition for this connection is that the estimating system relates construction costs to materials and semi-finished products, of which the eco-costs are known.

Of course, eco-costs concerning the whole life-cycle of the project should be considered. So, what is concluded for estimating construction costs (affected in the production phase), should be extended to estimating the costs in the operating and the end-of-life phase of the project. This implicates that the project development process should contain operating estimates that relate operating costs to materials and semi-finished products, of which the eco-costs are known.

6.2.2 Value

What is a meaningful approach of the concept of 'value' in the context of relating environmental burden to that 'value' as a result of design decisions concerning interventions in the housing stock?

In Chapter 3 it is concluded that a meaningful concept of value in the context of the EVR should relate to product quality dimensions 'as perceived by the customers'. To make this idea operational, a tentative elaboration of the 'customer value model of Gale' has been produced. This customer value model has been connected to the observations by Brand and Thomsen concerning the periodicity of adaptations in existing dwellings in the housing stock. On this basis, a model has been produced concerning the quality and value development of aging houses.

The case studies in Chapter 5 show that, on the level of housing expenses, the EVR of refurbished and extensively renovated apartments are lower than the EVR of new construction. However, the value of refurbished and renovated houses, as compared to the value of newly-constructed houses, depends on the perception of the quality dimensions in the various categories by the customers. In order to be able to develop strategies for optimising the quality dimensions that can be obtained by the various interventions, further research of 'customer quality' is advised.

6.2.3 Process

What requirements are set by design and development processes for a decision-support tool referring to eco-costs in particular during the early process stages?

Decision-support tools should be closely connected to the available building design and development processes. In these processes, strategic decisions, on a high scale level, are taken in the initiatory phase: Will the intervention be based upon refurbishment, renovation or redevelopment?

Chapter 5 shows that not just the traditional costs but also the eco-costs are largely determined by the decisions on this high scale level. Within the value range as set by factors related to location (housing status) and general economic circumstances, however, the (customer) value of a certain plan alternative depends upon product qualities that are often related to building characteristics on a lower scale level. Therefore, architects should be able to evaluate aspects of their design alternatives on this lower scale level, without the necessity for elaborating the complete design to that level. So, estimating tools need to offer cost information that can be used to evaluate design alternatives on different scale levels simultaneously, connecting the information on the discerned levels in a way that excludes double counting or omission.

In the initiatory phase, the budget available for feasibility studies is usually quite modest. The developed reference projects model offers the required connection of cost information on different scale levels for both traditional costs and eco-costs. Moreover, the model is connected to a working method that many architects basically use in practice.

The model has been elaborated in such a way that the required input data correspond with those of the operating estimates that are usually produced in this phase of the design process, and also with those of the energy demand estimating tool.

In principle the model can be concluded to have the right combination of characteristics to be promising. (Application in practice, however, has been started too recently to draw further conclusions in this respect.)

6.2.4 The EVR of housing

What can be expected of applying a tool based on the EVR model in terms of reducing the ecological burden of housing (in general and on project level)?

The case studies in Chapter 5 show that new construction on the one hand and renovation and refurbishment on the other hand need different approaches as for improving their performances related to ecological burden:

In new construction projects, the eco-costs are primarily caused by the construction materials in the production phase. So, the application of alternative materials or the improvement of production of the materials that have a high EVR is indicated in these projects.

In renovation and refurbishment projects, the eco-costs are mainly due to the alleged inferior performances in the operating phase of the buildings in relation with the required energy for heating etc. So for these projects, more emphasis on measures that can reduce energy consumption in that phase is needed.

In the case of extensive renovation, the housing expenses – on the one hand – sharply increase and are almost on the same level as the expenses in case of new construction. On the other hand, a larger part of the housing expenses of renovation consists of energy costs. These energy costs raise the EVR of extensive renovation. Still, it remains far below the EVR of new construction. The larger part of the costs being energy costs, offers the tenant a firmer grip on his housing expenses. He can decide to be economical with heating if financially necessary. Moreover, eco-costs connected to operating expenses and energy costs, in a way, imply opportunities for intermediate measures in the field of 'cleaner energy'.

The general conclusion, however, is that the ecological burden of housing is by far due to the pollution caused by the consumption of (fossil) energy. A revived emphasis on 'cleaner' energy – in order to reduce the EVR of energy consumption – would be very effective for all categories of housing.

6.3 Evaluation

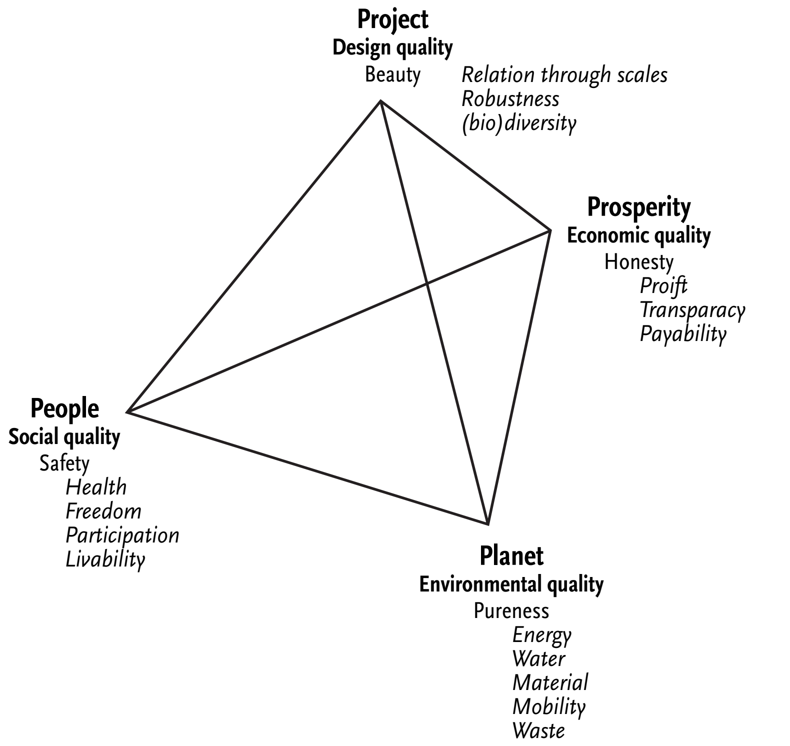
6.3.1 Profit – planet – people

Referring to Our common future (Brundtland 1987), sustainability is often indicated as related to the '3 Ps: profit, planet and people'. For sustainability in construction, Duijvestein added a fourth P: 'project' (Duijvestein, 2004). This way the pyramid (tetrahedron) of Figure 6.1 emerges from the 3-Ps-triangle.

The EVR model, as elaborated in this study for housing investments, can obviously provide relevant information about 'profit and planet' as related to the 'project'. In the pyramid, this relation is represented by the face: project – profit – planet. On project level, the model relates the economic aspects of housing to the ecological aspects, in the various stages of the life cycle of houses, by comparing traditional costs to eco-costs.

The model also addresses certain aspects of the 'people' dimension of sustainability in housing. The value aspect in the model, being expressed as customer value, relates the resident's preferences to the economic and ecological sacrifices involved in varying possibilities of housing quality levels. In the housing sector, this relation between 'people' on the one hand and 'profit and planet' on the other hand is mystified by market imperfections.

Figure 6.1 Sustainable building presented in Quadruple P (people, planet, prosperity and project)



Source: Duijvestein, SOOMBOOMDIOC

In the metaphor of the pyramid, the value aspect of the EVR model corresponds with the faces: project – people – profit and project – people – planet. Actually these faces of the pyramid can be considered to contain the traditional mission of the architect: to create a building that facilitates people's relations to their environment. In the context of sustainability, this mission should obviously include a sustainable balance between the people and the environment.

As mentioned before, the EVR model indicates which aspects of a plan entail more or less environmental burden, expressed in costs (for society) to compensate this burden (outside the project). The model as such does not provide solutions. As far as these solutions can be found on the level of a particular building project, the involved stakeholders should find them. In order to do so, they may use qualitative methods that indicate the possibilities of alternative solutions and materials, like the DCBA method (Duijvestein, 1998), the National Sustainable Building Packages (DUBO, 2003) or the MRPI (MRPI, 2003). The impact of the selected solutions can subsequently be evaluated by the EVR model. All relevant 'EVR data' concerning the solutions should obviously be involved in that process: traditional costs, eco-costs and (customer) value, both in the production phase and the operating phase.

6.3.2 Sustainable quality and cost levels

Establishing a reasonable policy, concerning sustainable quality and cost levels to achieve in the housing stock, is not easy. How much living area, for instance, do people really want in their houses, if they could choose from different sizes and related price levels? What level of finishing would they prefer? And what can they afford if eco-costs are charged on?

Table 5.5 shows a large increas of rent and housing expenses, whatever intervention is taken (in the 40-year-old apartment block), be it refurbishment, extensive renovation or new construction. It is questionable if the purchasing power of the present residents or the target group is big enough to pay the new rent. That would be even more so, if eco-costs were transferred into real costs (e.g. when government introduces tradable emission rights).

The figures in Table 5.5 are based on cost price calculations. So, one might suggest to reduce rent levels by subsidising refurbishment or renovation, because they produce less ecological burden than new construction does. This, however, would bring housing out of balance with other products or services as to the efforts concerning the reduction of ecological burden in general. In the end, less reduction would be the result.

Solving these problems of sustainability, related to socio-economic questions of income division, is beyond the scope of the EVR model for housing. Further investigations related to the customer value model (of Gale) and the housing status/dwelling quality relationship (according to Phe and Wakely) may result in some more knowledge in this respect.

6.3.3 Other buildings

Section 5.3.5 concludes that energy (for heating) is an important factor in sustainability during the operating phase of houses. In other building categories, energy consumption (for heating and air conditioning) is considered to be equally important, as can be deduced, for instance, from the efforts the government in the Netherlands displays concerning energy savings in non-residential buildings (EPA 2004). The EVR model, as elaborated in this study, can be applied in those sectors as well in order to integrate energy saving measures in an overall life-cycle approach of sustainability. Further research in this direction should be aimed at the materials flow and value development of these buildings.

6.3.4 Political sustainability targets

The model of the Eco-costs/Value Ratio, as elaborated for housing in this thesis, provides an insight into the different ecological effects of choices on project level referring to interventions in the housing stock. A major advantage

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of the model is that it provides information in a relatively comprehensible way, and therefore can be used by stakeholders who are not specialised in ecology. So, in principle, the stakeholders in the projects are able to make their own examinations referring to the ecological impact of their choices.

The Eco-costs/Value Ratio can bring the individual projects in line with the political sustainability targets on a regional or global level. A sustainable approach, however, is not yet reached by this adjustment alone. In the end, politics will have to set the targets and the constraints in which a model as developed in this thesis can function. Or, as Brundtland states: "… sustainable development has to rest on political will." (Brundtland, 1987, p.9)

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Samenvatting

Economische doelmatigheid van investeringen in duurzame woningbouw

Inleiding

Dit onderzoek betreft de duurzaamheid van het bouwen en het gebruiken van gebouwen in de Nederlandse woningbouwsector, als voorbeeld van de situatie in West Europa. Aangezien het grootste deel van de problemen met duurzaamheid in de woningbouw gelokaliseerd kan worden in de bestaande voorraad, is het doel van het onderzoek de ontwikkeling van een besluitvormingondersteunend model voor interventies in deze voorraad, dat wil zeggen voor renovatie en herontwikkelingsprojecten. Dit instrument moet informatie verschaffen over de milieubelasting van de projecten, in relatie tot de kenmerken van het ontwerp op de – voor de verschillende procesfasen gebruikelijke – schaalniveaus. Het instrument moet ingezet kunnen worden in het hele ontwerpproces, vanaf de projectdefinitie tot en met de besteksfase.

Het onderzoek sluit aan bij het model van de Ecokosten/Waarde Ratio (Vogtländer, 2001). Het betreft de toepasbaarheid van het model als instrument in de ontwerp- en besluitvormingsprocessen die voorafgaan aan interventies in de woningvoorraad. De probleemdefinitie van het onderzoek is dan ook als volgt geformuleerd:

Is het begroten van ecokosten en het afwegen ervan tegen de beoogde waarde, op projectniveau, een bruikbare manier om ex ante de milieubelasting van (alternatieve) plannen voor interventies in de woningvoorraad te evalueren, in het bijzonder in de vroege fase van de planontwikkeling?

Om een antwoord te vinden op deze onderzoeksvraag begint de studie met een onderzoek naar de begrippen ‘Ecokosten van wonen’ en ‘Waarde van woningen’. Vervolgens gaat het onderzoek in op de vraag, welke eisen door de ‘Ontwerp- en ontwikkelingsprocessen’ gesteld worden aan een besluitvormingsondersteunend instrument met betrekking tot ecokosten.

Op basis van de conclusies van dit onderzoek is een prototype gemaakt voor een instrument waarmee zowel ecokosten als traditionele kosten geraamd kunnen worden betreffende het (ver)bouwen en exploiteren van woongebouwen, in de context van interventies in de woningvoorraad.

Ten slotte zijn enkele casestudies uitgevoerd om te evalueren wat verwacht kan worden van de toepassing van een instrument, dat gebaseerd is op de ‘Ecokosten/Waarde Ratio van wonen’.

De ecokosten van wonen

Methoden op basis van LCA
Om te beginnen worden modellen onderzocht, die de milieubelasting van bouwprojecten kunnen kwantificeren. De meest systematische methode op dit terrein is de Levenscyclusanalyse (LCA). De LCA biedt een systematische aanpak voor het meten van de uitputting van natuurlijke bronnen en van de uitstoot van (schadelijke) stoffen die gemoeid zijn met producten, processen en diensten. De traditionele LCA wordt echter vaak als te gecompliceerd en te specialistisch beschouwd om als besluitvormingsondersteunend instrument in de planontwikkeling te kunnen dienen. Alleen milieuexperts zijn in staat ze te interpreteren, en zelfs hun complexe beslissingen zijn niet eenvoudig over te brengen aan de belanghebbenden in de projecten. In de literatuur kunnen dan ook verschillende methoden gevonden worden, die de milieubelasting van gebouwen uitdrukken in een enkelvoudige indicator. Al die methoden laten ten aanzien van doel en reikwijdte kleine verschillen zien. Drie op de LCA gebaseerde methoden zijn nader bestudeerd: Eco-Quantum, Green-Calc en de methode van de Ecokosten/Waarde Ratio (Eco-costs/Value Ratio, EVR).

De Ecokosten/Waarde Ratio
Anders dan bij Eco-Quantum en Green-Calc, is het conceptuele model van de EVR (Ecokosten/Waarde Ratio) onafhankelijk van het soort product waarvan de milieubelasting wordt bepaald. De EVR is een op de LCA gebaseerde bepalingsmethode die de milieubelasting van een product of dienst uitdrukt in 'ecokosten'. De ratio vergelijkt de 'ecokosten' met de waarde van het product of de dienst. Een lage EVR geeft aan dat het product geschikt is voor gebruik in een toekomstige duurzame samenleving. Een hoge EVR geeft aan dat de verhouding waarde/kosten van een product in de toekomst 'minder dan één' kan worden, als de 'externe' kosten van de milieubelasting deel gaan uitmaken van de 'interne' kostenstructuur. Dat wil zeggen dat er in de toekomst voor zo'n product geen markt is (Vogtländer, 2001).

In principe kan met de EVR de omvang van de milieubelasting van allerlei soorten gebouwen worden aangegeven, mits de waarde van de gebouwen vergelijkbaar is. Bovendien kunnen nieuwbouw en renovatie of onderhoud ten aanzien van de milieubelasting met elkaar vergeleken worden. Daar in het bijzonder deze laatste eigenschap nodig is voor een instrument dat gericht is op interventies in de bestaande woningvoorraad, wordt het vervolg van het onderzoek toegespitst op de mogelijkheden van de EVR.

Een van de centrale ideeën van de EVR methode is ecokosten te definiëren als de kosten van technische maatregelen die vervuiling en uitputting van grondstoffen tegengaan tot een niveau dat voldoende is om de samenleving duurzaam te maken. Preciezer gezegd is de methode gebaseerd op de 'virtual eco-costs '99': de som van de marginale preventiekosten betreffende de uitputting van materialen, energieconsumptie, toxische emissies, arbeid en afschrijving, die verbonden zijn aan de productie en het gebruik van producten en diensten. Zoals alle methoden die gebaseerd zijn op de LCA, omvat de EVR methode de hele levenscyclus van een product. In het geval van woningen of andere gebouwen moeten ten minste drie fasen van de levenscyclus van het product apart beschouwd worden: de productiefase, de exploitatie- of gebruiksfase en de einde-levensfase.

Productiefase

Een belangrijke eigenschap van bouwprojecten is dat ieder project bestaat uit een combinatie van halfproducten die op de bouwplaats worden samengevoegd. Dientengevolge mag ervan uitgegaan worden dat de milieubelasting (de ecokosten) van een gebouw bestaat (bestaan) uit de ecokosten van die halfproducten plus de ecokosten van de assemblageactiviteiten (inclusief alle bijkomende werkzaamheden zoals werkvoorbereiding, bouwplaatsinrichting en management). Het is dus in principe mogelijk de ecokosten van een gebouw te begroten op basis van 'eco-eenheidprijzen' van bouwkundige elementen. Zoals bij een traditionele kostenraming op basis van eenheidprijzen wordt de samenstelling van de betreffende elementen bepaald in termen van hoeveelheden kenmerkende halfproducten en assemblageactiviteiten. Voor deze producten en activiteiten kunnen de gegevens betreffende emissies en uitputting, waarop de bepaling van de ecokosten gebaseerd is, gevonden worden in databases zoals IDEMAT, Eco-Invent en MARKAL. Vervolgens kunnen de ecokosten per eenheid element vastgesteld worden door de ecokosten van halfproducten en assemblageactiviteiten in de recepten van de elementen in te vullen. Ten slotte kan de elementenbegroting (die gemaakt is voor de bepaling van de traditioneel economische kosten) worden omgezet in een ecokostenbegroting door de traditioneel economische eenheidsprijzen te vervangen door ecokosten eenheidsprijzen.

Op deze manier zijn ecokosten ingevoerd in de materialen-database van een begrotingssysteem dat gebruikt wordt om elementenbegrotingen te maken van de bouwkosten van nieuwbouw- en renovatieprojecten. Zo is een instrument verkregen voor het begroten van ecokosten in de productiefase van dit type projecten.

Exploitatiefase

In de exploitatiefase wordt de milieubelasting in hoofdzaak bepaald door de energiebehoefte en het onderhoud van het gebouw in gebruik. Om de besluitvorming in de ontwerpfase – voorzover die betrekking heeft op de energiebehoefte – te ondersteunen, is gebruik gemaakt van een bestaande methode (DGMR, 2004). Architecten kunnen met deze methode ramingen maken van de energiebehoefte van woongebouwen (in Nederland). Het komt de toepasbaarheid van de methode in de ontwerpfase ten goede dat de voor de berekeningen benodigde gegevens zijn beperkt tot de belangrijkste vormeigenschappen van de gebouwen. De voorziening van deze methode, waarmee de energiebehoefte wordt berekend, kan gemakkelijk geïntegreerd worden in de EVR benadering.

In de afgelopen jaren zijn in Nederland verschillende managementmethoden ontwikkeld voor onderhoud. Deze methoden lijken echter te complex voor gebruik in de (vroege) ontwerpfase. In deze fase zijn uitgebreide begrotingen van onderhoudsinspanningen heel ongebruikelijk. Aan de Technische Universiteit Delft is een ramingmethode uitgewerkt om de invloed van ontwerpbeslissingen op de onderhoudskosten van woongebouwen te onderzoeken. Vanwege zijn eenvoudige structuur en zijn koppeling aan de NEN 2634 kan deze methode geschikt zijn voor toepassing door (Nederlandse) architecten in de vroege fasen van het ontwerp. Hij kan worden geïntegreerd in de EVR benadering.

In de woningbouwsector zijn de kosten van administratie en beheer in de regel tamelijk onafhankelijk van het specifieke gebouwontwerp. Voor een schatting van de betreffende ecokosten kan het uitgangspunt zijn, dat deze kosten vooral betrekking hebben op ‘arbeid in kantoren’.

Einde-levensfase
De kosten van sloop en afvalscheiding vallen onder de traditioneel economische kostenbepaling. De kosten ter voorkoming van vervuiling door deze activiteiten kunnen zonder grote problemen geraamd worden. De ecokosten van recyclen en upgraden worden toegewezen aan de nieuwe producten, die deze processen voortbrengen. Dus hebben alle ecokosten in de einde-levensfase na de afvalscheiding betrekking op de afvalfractie die niet geschikt is voor upgraden of recyclen. Deze fractie wordt belast met de ‘ecokosten van afval storten’.

Tot zover is een conceptueel model ontwikkeld voor het begroten van ecokosten in de hele levencyclus van woningen. Het onderzoek gaat verder met het probleem van afweging van de ecokosten ten opzichte van de waarde van een woning en met het probleem van het onderling wegen van de ecokosten in de verschillende fasen van de levenscyclus.

De waarde van woningen

Verschillende benaderingen van waarde
Aangezien in de woningbouwsector veel verschillende methoden worden toegepast voor het bepalen van waarde, rijst de vraag welke manier van waardebepaling in deze context relevant is.

In de (originele) EVR methode wordt de waarde – het bedrag waarvoor een product of dienst in een open markt verhandeld kan worden – bepaald door de 'verkoopprijs' in de handelsketen en de 'billijke prijs' op de consumentenmarkt. Voor gebruiksgoederen, waarvan dagelijks veel exemplaren worden verkocht, kan de waarde van producten vastgesteld worden door observatie van verkoopprijzen. In vastgoed en woningmarkten is het echter veel minder gemakkelijk om op deze manier de waarde van producten vast te stellen.

Het onderzoek naar de waarde van woningen begint met een theoretische uiteenzetting die kan worden samengevat in de volgende stellingen, die gelijktijdig van toepassing zijn:

- De waarde van woningen wordt bepaald door de (netto contante waarde van) toekomstige opbrengsten.
- De waarde van woningen is gerelateerd aan de (actuele) stichtingskosten van woningen.
- De waarde van woningen houdt verband met de gewenste eigenschappen/prestaties.
- De waarde van woningen neemt geleidelijk af ten gevolge van innovaties.
- De waarde van woningen fluctueert door een combinatie van onderhoud en prestatieverlies.
- De waarde van woningen is gerelateerd aan de locatie in samenhang met het compromis tussen status en de maatschappelijke aanvaardbaarheid van woningkwaliteit.
- De waarde van woningen wordt beïnvloed door woningmarktfactoren (zoals een algemeen tekort aan woningen) en andere economische factoren (zoals het renteniveau).

Waarde en kwaliteit

Daar beslissingen in ontwerpprocessen vooral betrekking hebben op fysieke (gebouw)eigenschappen van woningen, is het onderzoek gericht op het vaststellen van een verband tussen deze eigenschappen en de waarde van woningen.

In dat verband worden de ideeën van Garvin met betrekking tot de kwaliteitsdimensies – tentatief – uitgewerkt voor de Nederlandse woningbouwsector (Garvin, 1988). Voor deze kwaliteitsdimensies is essentieel dat ze worden bepaald door de producteigenschappen, 'zoals die door de klanten worden waargenomen'. In de opvatting van Garvin kan kwaliteit alleen door de klanten worden beoordeeld. Wat betreft woondiensten kan de waarde voor de huurders, die hier de klanten zijn, worden uitgedrukt door de billijke huurprijs. In het 'customer value model' (Gale, 1994) – dit is een methode om de waarde voor de klant te analyseren – wordt zo'n billijke huurprijs gerelateerd aan de waardering van de klanten voor de verschillende kwaliteitsdimensies van de betrokken woningen.

Waarde en tijd

De uitwerking van het 'customer value model' is gekoppeld aan waarnemingen betreffende de periodiciteit van aanpassingen aan bestaande woningen (Brand, 1994), aan de ontwikkeling van de hoeveelheid woningoppervlakte per persoon en aan de capaciteit die de bouwnijverheid in Europa beschikbaar heeft voor de vervanging van de woningvoorraad (Thomsen, 2002). Op grond hiervan is een model gemaakt van de relatie tussen de waardeontwikkeling van ouder wordende woningen en de ontwikkeling van de onderscheiden kwaliteitsdimensies van die woningen. Vastgesteld is dat de op basis van dit model geschatte waardeontwikkeling van woondiensten correspondeert met andere bevindingen op het gebied van de veroudering van woningen in de Nederlandse huursector (Conijn, 1995).

Locatie-aspecten

In de regel neemt de waardering voor de kwaliteitsdimensies in de loop van de tijd af. Na afloop van een periode van 30 jaar na de oorspronkelijke bouw van een woning zal het eindcijfer voor de kwaliteit, en daarmee de waarde voor de klant, ongeveer 65% bedragen van het cijfer, c.q. de waarde van de nieuwe woning. Veranderingen in de huisvestingsstatus van een bepaalde locatie (Phe en Wakely, 2000) kunnen deze waardeontwikkeling verstoren. Gewoonlijk liggen in een bepaalde buurt de fysieke kwaliteiten van de meeste huizen min of meer op hetzelfde niveau. Daardoor zal deze verstoring nauwelijks invloed hebben op de relatieve waarde (dit is de marktpositie) van de ouder wordende huizen in de betreffende buurt.

De waarde van woningen die herinvestering nodig hebben

De waarde die een woning heeft als vastgoedobject voor een verhuurder, is gelijk aan (de contante waarde van) de toekomstige netto opbrengsten. Aanbevolen wordt dat de toekomstige netto opbrengsten worden geschat met inachtneming van de bovengenoemde vermindering van het kwaliteitsoordeel betreffende de woondiensten, die door de woning worden geleverd. Daarbij moet bedacht worden dat na een periode van 30 jaar de kwaliteit van de woning (door de klanten) onvoldoende gevonden zal worden en dat voor voortgezette exploitatie dus waarschijnlijk een herinvestering nodig is. Een schatting van de (rest)waarde van de woningen op dat moment zou moeten plaatsvinden op basis van de verwachte afname van de verschillende kwaliteitsdimensies van de geleverde woondiensten (met behulp van het model van Gale) en de mogelijkheden om de kwaliteit, en de waarde, te herstellen door groot onderhoud, ingrijpende renovatie of (vervangende) nieuwbouw. Dus wordt restwaarde aan het eind van de exploitatieperiode verkregen uit het verschil van de waarde van de woning na een ingreep op dat moment en de (stichtings)kosten van diezelfde ingreep.

$V_e = V_n - C$

Waarin V_e = (rest)waarde van de bestaande woning
V_n = waarde van de nieuw woning die ontstaat door de ingreep
C = stichtingskosten van de ingreep

Ontwerp- en ontwikkelingsprocessen

Flexibel ontwerpproces in een formeel ontwikkelingsproces

Terwijl een architect in het ontwerpproces heel goed op en neer kan gaan in de verschillende lagen van de hiërarchische opzet van het ontwerp voor een gebouw, om diverse ontwerpalternatieven op verschillende niveaus te evalueren, heeft hij in het formele ontwikkelingsproces veel minder vrijheid.

Als in de praktijk een bepaalde fase wordt afgerond door een officiële goedkeuring van de opdrachtgever, kunnen alleen buitengewoon ernstige argumenten het proces laten terugkeren naar die fase, anders zouden de economische belangen van de betrokken partijen te veel schade ondervinden. Vanwege dit statische karakter van de inrichting van het ontwikkelingsproces, vergeleken met de inrichting van het ontwerpproces, moeten architecten en andere professionele deelnemers aan de voorbereiding van bouwprojecten op een soepele manier de ‘ontwerpladder’ op en af kunnen gaan om de mogelijkheden van interessante alternatieven op verschillende schaalniveaus in het ontwerp te evalueren. Vooral in de vroege fasen van het ontwerp kan het voorkomen, dat architecten verschillende alternatieven (op lagere schaalniveaus) heel snel willen evalueren, omdat voor een uitgebreid onderzoek in die fasen gewoonlijk geen budget beschikbaar is.

Begrotingsinstrumenten zouden in staat moeten zijn dit snelle ‘op en neer’ gaan te volgen. Met andere woorden: Ze moeten kant-en-klare kosteninformatie leveren, die gebruikt kan worden om ontwerpalternatieven op verschillende schaalniveaus simultaan te evalueren. Daarbij moeten ze de informatie op de onderscheiden niveaus zo met elkaar verbinden dat dubbeltellingen of omissies niet voor kunnen komen.

Eisen aan een begrotingsmethode

Zoals eerder opgemerkt spelen de milieubelasting, en bijgevolg de ecokosten, in alle fasen van de levenscyclus van woningen een rol. Daarom moet het ramen van ecokosten de reikwijdte hebben van de benadering middels ‘Life Cycle Costing’ (LCC). Om aan te sluiten bij in woningbouw gebruikelijke methoden kan hiervoor het best de techniek van de zogenaamde exploitatieberekening ingezet worden, waarbij bijvoorbeeld onderhoud en energiekosten afgestemd kunnen worden op verschillende specificaties in het ontwerp.

Veel architecten geven er de voorkeur aan wat betreft bouwkosten terug te vallen op hun eigen ervaringen uit voorgaande ontwerpopdrachten voor vergelijkbare gebouwen. Dat doen ze vooral omdat in de vroege procesfasen meestal geen beter alternatief voorhanden is.

Het gebruik van deze zelfgemaakte kostengegevens voor de vroege procesfasen heeft verschillende nadelen:

- Ze zijn niet in staat relevante informatie over ecokosten te verschaffen omdat ruwe data over dit onderwerp niet voorhanden zijn.
- De (meeste) projectdocumenten van architectenbureaus zijn niet zo geordend, dat de kostengegeven erin gemodelleerd kunnen worden naar de (belangrijkste) afmetingen van het voorlopig ontwerp.
- In het algemeen sluiten de kostengegevens van deze referentieprojecten slecht aan bij de gegevens van latere fasen in het ontwikkelingsproces.

Daar komt nog bij dat er in het proces al snel behoefte zal ontstaan aan meer gespecificeerde kostengegevens. Waarschijnlijk zijn in het ontwerp dan alternatieve bouwvormen aan de orde en worden verschillende combinaties van functionele of ruimtelijke eenheden overwogen. De technische specificatie van bouwkundige elementen kan dan echter nog ver weg zijn. In dit stadium van het voorlopig ontwerp is informatie nodig die de kosten relateert aan de alternatieve combinaties van (functionele) projectdelen en aan wisselende afmetingen van gebouwen.

Voor de procesfasen van het definitief ontwerp en het bestek is er geen behoefte aan kosteninformatie betreffende gespecificeerde elementen (technische oplossingen) en komt die informatie beschikbaar ook niet beschikbaar, aangezien de detaillering van het ontwerp nog niet zover is voortgeschreden. Pas in deze eindstadia van het ontwerp worden de kosteneffecten van de toepassing van verschillende materialen en halfproducten op een uitgebreidere schaal in beschouwing genomen.

Dus een begrotingsmethode moet nauw aansluiten bij de eisen vanuit het ontwerpproces. Dat wil zeggen: gespecificeerd zijn als dat nodig is, maar globaal als de betreffende beslissingen een globaal karakter hebben. Bovendien moet de methode, zoals eerder opgemerkt, in staat zijn de architect de ‘ontwerpladder op en af’ te volgen.

De ontbrekende schakel

Hier ontbreekt bij de bestaande instrumenten voor het maken van kostenbegrotingen blijkbaar een schakel. Aan de top van de hiërarchische opzet van het ontwerp, is er meestal een algemeen idee van de bouwkosten, gebaseerd op de vierkantemeterprijzen van eerder ontworpen projecten. Aan de onderkant van het model zijn soms eenheidsprijzen van technische oplossingen beschikbaar uit een database van kostenanalyses, waarin door middel van element-recepten een verband wordt gelegd tussen de gespecificeerde elementen (technische oplossingen) en de kosten van materialen, arbeid etc.

Daartussen echter geven de bestaande begrotingsinstrumenten geen informatie over welke combinatie van technische oplossingen karakteristiek is voor het type gebouw waar het in het betreffende project om draait.

Om deze ontbrekende schakel aan te vullen is de Referentie Projecten Methode ontwikkeld. Die voorziet in de nodige gegevens op basis van het idee dat (binnen een vastgoedmarkt regio, bijvoorbeeld Nederland) een gebouw een uniek product is, niet zozeer omdat het bestaat uit unieke technische oplossingen, maar veeleer omdat het een unieke combinatie is van (op zich) vergelijkbare technische oplossingen.

De Referentie Projecten Methode

Het idee achter de Referentie Projecten Methode is dat een architect de bouwkosten van een nieuw ontwerp afleidt uit de bouwkosten van een project dat hij al kent: het referentieproject. Het is duidelijk dat projecten met door de architect zelf ontworpen gebouwen voor hem de beste referentieprojecten zijn. In het algemeen kan een architect dus zijn nieuwe projecten het best relateren aan andere projecten uit zijn eigen portfolio.

In twee situaties gaat deze stelling – voor het afleiden van bouwkosten – niet op:

- als de architect met een opdracht geconfronteerd wordt met betrekking tot een categorie gebouwen waarmee hij nog geen ervaring heeft opgedaan;
- als de architect geen adequaat geordende kostengegevens betreffende de reeds eerder door hem ontworpen projecten beschikbaar heeft.

In deze situaties kan een publieke database van referentieprojecten de 'op-een-na-beste' kostengegevens verschaffen voor de vroege procesfasen. De Referentie Projecten Methode is ontworpen als zo'n database (Winket, 2004).

Met de methode kunnen architecten (en opdrachtgevers) in alle stadia van het ontwikkelingsproces op een passend schaalniveau begrotingen maken van de kosten van woningbouwprojecten. Wat betreft de begrotingstechniek is er in de methode maar één verschil tussen traditionele bouwkosten en ecokosten: ecokosten kunnen niet geverifieerd worden op basis van gerealiseerde aanbestedingsprijzen.

Instrument voor de Ecokosten/Waarde Ratio in woningbouwprojecten

In deze fase van het onderzoek is voor het maken van begrotingen betreffende de productiefase en de einde-levensfase de Referentie Projecten Methode operationeel. Voor begrotingen betreffende de exploitatiefase kunnen de spreadsheet voor het ramen van energiebehoefte (DGMR, 2004) en het Delftse model voor het ramen van onderhoud gekoppeld worden aan de inputinterface van de Referentie Projecten Methode. Deze combinatie van instrumenten voor de exploitatiefase behoeft nog enige technische uitwerking voordat hij gereed is voor gebruik door architecten in echte projecten in de praktijk.

De Ecokosten/Waarde Ratio van wonen

De Ecokosten/Waarde Ratio op investeringsniveau

Om te laten zien welke resultaten met behulp van de ontwikkelde modellen verkregen kunnen worden, zijn twee casestudies uitgevoerd. Eerst worden de resultaten gepresenteerd van ecokosten-berekeningen in veertien recent gebouwde projecten. De nadruk bij deze projecten ligt op woningbouw, dat wil zeggen zowel nieuwbouw als renovatie. Er zijn ook enkele utiliteitsbouwprojecten toegevoegd om een (voorlopige) indicatie te krijgen van de positie van de woningbouwsector ten opzichte van andere sectoren in de bouw.

De resultaten van deze berekeningen laten zien dat de Ecokosten/Waarde Ratio van de nieuwbouw van woningen en de nieuwbouw van kantoren op een vergelijkbaar niveau liggen. Renovatie blijkt echter een significant lagere Ecokosten/Waarde Ratio te hebben dan nieuwbouw. Analyse van de begrotingsresultaten geeft aan dat dit verschil tussen nieuwbouw en renovatie vooral samenhangt met de combinatie van de relatief hoge milieubelasting, die de elementen van Onderbouw, Skelet en Schil van de gebouwen in de productiefase laten zien, en het feit dat deze elementen in nieuwbouw- en renovatieprojecten verschillend aangepakt worden.

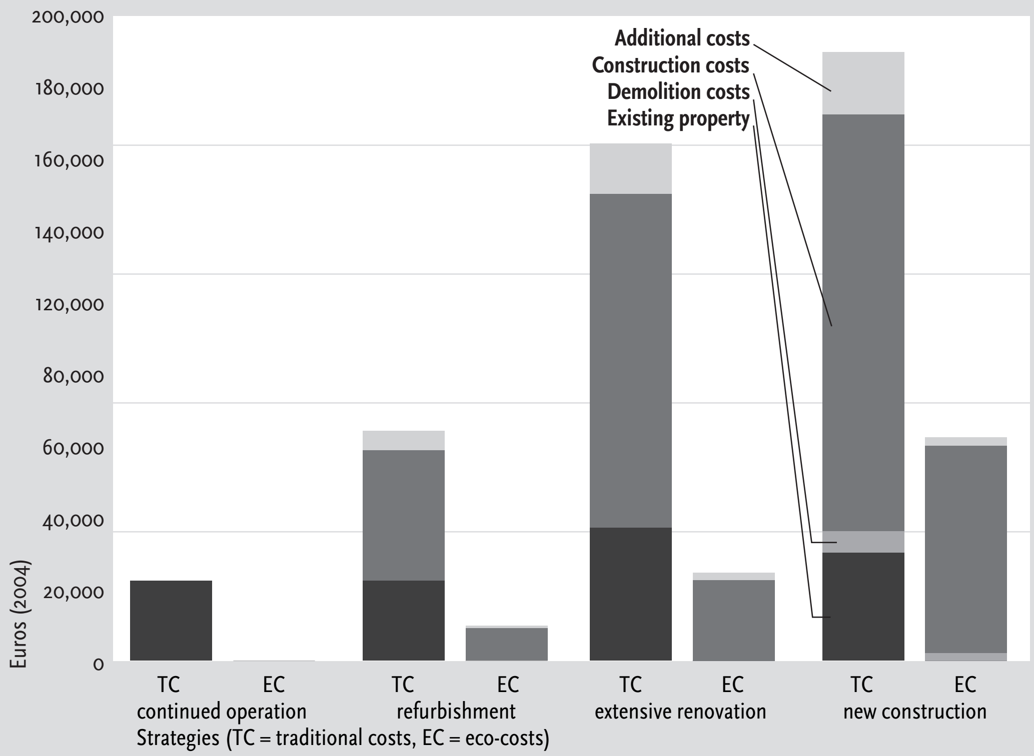
Analyse van de begrotingsresultaten geeft ook aan dat het grootste deel van de ecokosten van gebouwen in de productiefase kan worden teruggevoerd op een relatief kleine groep materialen.

Toepassing ERV methode bij interventieprojecten in de woningvoorraad

Op basis van praktijkervaring in diverse (vervangende) nieuwbouw- en renovatieprojecten, is een casus geconstrueerd waarmee de toepasbaarheid van het ontwikkelde model is getest: In een complex van ongeveer 200 appartementen gebouwd in de jaren zestig, wil de verhuurder, een Nederlandse woningcorporatie een interventieproject beginnen. Een voor zo'n project kenmerkende benadering is het uitvoeren van een haalbaarheidsstudie naar verschillende aanpakmogelijkheden, teneinde een gedegen projectdefinitie te kunnen opstellen.

Naast verkoop van de appartementen zijn in principe vier strategieën – dat zijn vier soorten ingrepen – mogelijk: ongewijzigde voortzetting van de exploitatie, groot onderhoud gericht op het verbeteren van een of meer kwaliteitsdimensies van de appartementen zoals ze zijn, ingrijpende verbetering gericht op het realiseren van (praktisch) nieuwe appartementen binnen het casco van het bestaande blok en ten slotte herontwikkeling gericht op het bouwen van geheel nieuwe woningen. Voor al deze strategieën zijn de investeringskosten (traditionele kosten en ecokosten) geraamd. De uitkomsten van deze investeringsramingen worden als traditionele kosten en ecokosten per appartement gepresenteerd in figuur A.

Figure A Traditional costs and eco-costs of investments at several strategies



Op het niveau van de investeringen is de EVR van nieuwbouw duidelijk het hoogst. Bovendien zijn, ook in reële cijfers, de stichtingskosten en ecokosten per appartement het hoogst bij nieuwbouw.

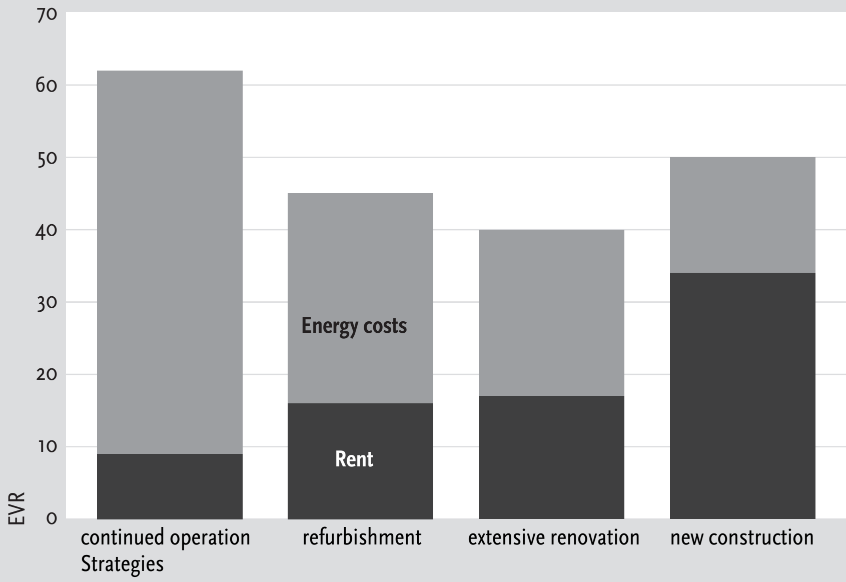
De Ecokosten/Waarde Ratio van woonlasten

De allocatie van ecokosten in de exploitatiefase gebeurt in overeenstemming met economische principes (alles gebaseerd op de Contante Waarde). Dit houdt in dat de ecokosten van de bedrijfswaarde (dit is de contante waarde van de exploitatie) gelijk zijn aan de ecokosten van investering. Met dit gegeven kunnen de ecokosten van het huren van woningen afgeleid worden op basis van de ecokosten van de investering en de ecokosten van de exploitatie-uitgaven.

Behalve uit huur bestaan woonlasten ook uit energiekosten. Het niveau van de energiekosten na de verschillende interventies wordt vastgesteld met behulp van de spreadsheet voor het ramen van energiebehoefte (DGMR, 2004).

In praktijkprojecten zou de haalbaarheid van verschillende strategieën beoordeeld kunnen worden op basis van een vergelijking van de begrotingsresultaten met de uitkomsten van een ‘customer value’ onderzoek. In deze casestudie wordt er echter van uitgegaan dat alle strategieën – met uitzondering van verkoop – resulteren in acceptabele woonlastenniveaus (voor verschillende doelgroepen) in de traditioneel economische betekenis. Met andere

Figure B Eco-costs/Value Ratio of housing expenses at several strategies



woorden: er kan van uitgegaan worden dat de woonlasten van de verschillende appartementen overeenkomen met de waarde van de daardoor geleverde woondiensten. Dus kan in overeenstemming met de methode van de Ecokosten/Waarde Ratio, de milieubelasting van de onderscheiden strategieën vergeleken worden met hun waarde door ze te vergelijken met de (traditioneel economische) woonlasten.

De op deze manier geraamde EVR van groot onderhoud blijkt lager te zijn dan de EVR van ongewijzigde voortzetting van de exploitatie. Zoals te zien in figuur B, heeft ingrijpende verbetering een nog lagere EVR. De EVR van nieuwbouw blijkt lager te zijn dan de EVR van voortgezette exploitatie, maar is hoger dan de EVR van renovatie.

Figuur B laat ook zien welk deel van de EVR veroorzaakt wordt door de huur en welk deel door de energiekosten. Bij groot onderhoud en renovatie bestaat een relatief groter deel van de woonlasten uit energiekosten dan bij nieuwbouw. Die energiekosten veroorzaken een stijging van de Ecokosten/Waarde Ratio bij groot onderhoud en renovatie. Toch blijven ze duidelijk beneden de EVR van nieuwbouw.

Tim de Jonge
Roosendaal, 2005

Appendix 1 EVR of labour for construction workers

The eco-costs of labour are indirect eco-costs, since labour as such is hardly causing any environmental burden. However, there is some environmental burden related to labour, such as the environmental impacts of heating, lighting, computers and commuting. The calculations of these eco-costs are specific for the type of labour. Vogtländer shows in his thesis an example of such a calculation for work in offices (Vogtländer, 2001, p. 33).

For workers on building sites different conditions have to be taken into account. In the eco-cost calculations, all the costs of equipment and facilities used by construction workers on building sites are designated to the building site costs. However, commuting expenses and the use of service vans, energy for production activities (on site) and working clothes are designated to the costs of labour.

The eco-costs of labour by construction workers are estimated as follows:

- Commuting 12,600 km per annum: 2,520 litres of petrol = 91 GJ
- Use of service vans 5,500 km per annum: 1,100 litres of petrol = 40 GJ
- Energy for building activities = 20 GJ
- Expenses for clothes en shoes = €412.00

■ Eco-costs:	91 GJ of petrol x €41.20	= € 3,749.00
	40 GJ of petrol x €41.20	= € 1,648.00
	20 GJ of electricity x €22.60	= € 452.00
	€412 x 44% (EVR)	= € 181.00 +
	Eco-costs per year	= € 6,030.00
■ Eco-costs per hour (1,460 hours per annum)		= € 4.13

In the analysis of the labour costs of an average construction worker, the grand total of costs per hour (Winket construction costs database, reference date 1-1-2004) is €34.50. So, the EVR of labour on building sites is €4.13/ €34.50 = 12%.

Appendix 2 Eco-costs of overheads in a medium-sized building company

Table A2.1 Eco-costs of overheads in a medium-sized building company, in euros (Reference date: 1-1-2004)

		Traditional costs		Eco-costs		Note
1	**Company premises**					
	building	90,400		36,160		1
	yard	11,800		-		2
	energy (natural gas; 408 GJ)	2,892		4,570		3
	energy (electricity; 94 GJ)	3,591		2,115		4
	interest, depreciation and repair concerning inventory	2,691		861		5
			111,374		**43,706**	
2	**Costs of machinery and equipment**					
	interest, depreciation and repair concerning:					
	hauling plant, compressors, scaffolds	4,837		726		6
	machines	-		-		6
	pneumatic tools	4,045		607		6
	hand tools	7,612		2,207		7
			16,494		**3,540**	
3	**Staff costs**					
	general manager	145,371		-		
	office assistant	28,200		202		8
	engineering draughtsman 50%	20,868		101		8
	clearing up workshop etc.	10,490		1,259		9
			204,929		**1,562**	
4	**Operating costs**					
	car (27,000 km, 200 GJ)	7,350		8,240		10
	4 service-vans (36,000 km, 270 GJ each)	37,880		-		11
	auditing costs	28,200		2,820		12
	office requirements	3,140		513		13
	insurance and taxes	8,650		-		
	sundries	1,900		570		14
			87,120		**12,143**	
5	**Interest charges of floating capital**					
	materials in stock	78,700				
	semi-finished products	76,610				
	receivables	283,620				
	floating capital in total	438,930				
	interest-rate	5,0 %	**21,947**		-	
	Total overheads per annum		**441,864**		**60,951**	
	EVR of overheads				**14%**	

Explanation

1.	Based on the EVR of the 'standard' office (Table 5.1)	40%
2.	Eco-costs of land not included	
3.	Based on eco-costs of natural gas (per GJ)	€11.20
4.	Based on eco-costs of electricity (per GJ)	€22.50
5.	Based on the mixed EVR (Vogtländer, 2001, p. 216) of	32%
	33% EVR of the wood industry	38%
	67% EVR of the metal products industry	29%
6.	Based on EVR (Vogtländer, 2001, p. 216) of machines	15%
7.	Based on EVR (Vogtländer, 2001, p. 216) of metal products	29%
8.	Eco-costs of commuting (Vogtländer, 2001, p. 33)	
9.	Eco-costs of labour on site (Appendix 1)	
10.	Eco-costs of petrol (per GJ)	€41.20
11.	Eco-costs designated to labour on site (Appendix 1)	
12.	Based on EVR of (external) labour in offices (Vogtländer, 2001, p. 33)	
13.	Products for 2.5 fte (Vogtländer, 2001, p. 33)	
14.	Based on an assumed EVR	30%

Appendix 3 Eco-costs of materials in the Winket database

Table A3.1 Traditional costs, eco-costs, EVR of materials, masses per unit, emissions per kg and depletion costs per kg of

STABU	Description		Traditional costs			Eco-costs		EVR	
			trad-cost mat./ unit	labour (h) per unit	trad-cost subc./ unit	eco-cost mat./ unit	eco-cost subc./ unit	EVR mat./ unit	EVR subc./ unit
21.32.10	traditional formwork of footings	m²	3.04	0.70		4.10		135%	
	traditional formwork of walls	m²	12.15	1.75		16.41		135%	
21.32.32	wall formwork (1 delling/day)	m²	2.25	0.25		11.43		509%	
	tunnel formwork (1 delling/day)	m²	2.25	0.25		11.43		509%	
21.33.10	dovetail sheet	m²	18.83	0.20		3.74		20%	
21.40.10	reinforcement steel FeB 500HK	kg	0.89	0.03		0.38		43%	
	reinforcement steel FeB 500HKN	kg	0.58	0.02		0.38		66%	
	starter bars d=20 mm 6x0.5 m	kg	0.89	0.15		0.38		43%	
21.50.10	concrete (320 kg cement) footings	m³	99.10	3.00		414.51		418%	
	concrete (320 kg cement) beams	m³	99.10	3.00		414.51		418%	
	concrete (320 kg cement) floor repair	m³	99.10	3.00		414.51		418%	
	concrete (320 kg cement) floors	m³	99.10	1.50		414.51		418%	
	concrete (320 kg cement) walls	m³	99.10	1.20		414.51		418%	
	concrete (320 kg cement) structure	m³	99.10	1.00		414.51		418%	
	concrete (320 kg cement) on wide slab	m³	99.10	1.20		414.51		418%	
21.51.10	monolithic concrete B35	m³	99.10	0.60		431.78		436%	
	finish by power trowelling	m²			5.82	-	0.73		13%
21.52.10	foam concrete surface	m³			46.93	-	10.62		23%
21.71.20	finishing concrete walls	m²		0.10		-			
21.81.11	polystyrene 100 se sheet 100 mm	m²	5.60	0.08		9.26		165%	
	polystyrene 100 se sheet 100 mm glued	m²	5.60	0.15		9.26		165%	
21.82.14	steel rim	m	4.28	0.10		2.38		56%	
21.82.22	drilling anchor	p			7.50	-	0.82		11%
22.00.28	wall ties	p	0.18			0.01		5%	
	drilled wall ties	p	0,.8	0.05		0.01		5%	
22.21.20	removal of jointing	mi				-			
	fitting profiles	p		0.50		-			
22.22.20	brickwork repair coloured hard-burnt	0/00	344.20		969.11	70.66	120.75	21%	12%
	mortar 500 l/1000	0/00	70.42			52.39		74%	
	brickwork repair sand-lime bricks	0/00	119.75		931.84	106.46	116.11	89%	12%
	mortar 500 l/1000	0/00	70.42			52.39		74%	
	fitting profiles	p		0.50		-			
22.23.20	wall injection (epoxy)	m			140.40	-	21.23		15%
22.24.00	facade cleaning high pressure	m²			14.10	-	2.60		18%
22.31.12	coloured bricks Waal size	0/00	314.50		596.38	111.61	74.31	35%	12%
	mortar 400 l/1000	0/00	56.33			41.91		74%	
	coloured bricks Waal size	0/00	314.50		596.38	100.98	74.31	32%	12%
	mortar 400 l/1000	0/00	56.33			41.91		74%	
	fitting profiles	p		0.75		-			
	coloured bricks Waal size	0/00	314.50		670.92	100.98	83.60	32%	12%
	mortar 400 l/1000	0/00	56.33			41.91		74%	

materials in the database (typical example)

greenh.	acidific. kg CO_2	eutroph. kg SO_4	heav.met kg PO_4	carcinog. als kg Pb	w.smog kg B(a)P	s.smog kg SPM	depletion kg C_2H_4	EUR/kg
3.15	1.26000	0.02100	0.00001	0.00000	0.00000	0.00040	0.00183	0.96
12.60	1.26000	0.02100	0.00001	0.00000	0.00000	0.00040	0.00183	0.96
30.00	1.13000	0.01310	0.00012	0.00002	0.00000	0.00095	0.00059	0.10
30.00	1.13000	0.01310	0.00012	0.00002	0.00000	0.00095	0.00059	0.10
5.80	1.75386	0.00975	0.00055	0.00000	0.00000	0.01212	0.00800	0.10
1.00	1.13000	0.01310	0.00012	0.00002	0.00000	0.00095	0.00059	0.10
1.00	1.13000	0.01310	0.00012	0.00002	0.00000	0.00095	0.00059	0.10
1.00	1.13000	0.01310	0.00012	0.00002	0.00000	0.00095	0.00059	0.10
2,400.00	0.06590	0.00036	0.00000	0.00000	0.00000	0.01140	0.00001	-
2,400.00	0.06590	0.00036	0.00000	0.00000	0.00000	0.01140	0.00001	-
2,400.00	0.06590	0.00036	0.00000	0.00000	0.00000	0.01140	0.00001	-
2,400.00	0.06590	0.00036	0.00000	0.00000	0.00000	0.01140	0.00001	-
2,400.00	0.06590	0.00036	0.00000	0.00000	0.00000	0.01140	0.00001	-
2,400.00	0.06590	0.00036	0.00000	0.00000	0.00000	0.01140	0.00001	-
2,400.00	0.06590	0.00036	0.00000	0.00000	0.00000	0.01140	0.00001	-
2,500.00	0.06590	0.00036	0.00000	0.00000	0.00000	0.01140	0.00001	-
4.00	5.55000	0.08250	0.00187	0.00011	0.00002	0.02050	-	0.60
4.00	5.55000	0.08250	0.00187	0.00011	0.00002	0.02050	-	0.60
6.24	1.13000	0.01310	0.00012	0.00002	0.00000	0.00095	0.00059	0.10
0.02	1.13000	0.01310	0.00012	0.00002	0.00000	0.00095	0.00059	0.10
0.02	1.13000	0.01310	0.00012	0.00002	0.00000	0.00095	0.00059	0.10
1,995.00	0.20800	0.00093	0.00000	0.00000	0.00000	0.00008	0.00002	-
808.68	0.12495	0.00062	0.00000	0.00000	0.00000	0.00225	0.00004	0.01
2,103.35	0.28900	0.00161	0.00000	0.00000	0.00000	0.00002	0.00004	-
808.68	0.12495	0.00062	0.00000	0.00000	0.00000	0.00225	0.00004	0.01
2,205.00	0.28900	0.00161	0.00000	0.00000	0.00000	0.00002	0.00004	-
646.94	0.12495	0.00062	0.00000	0.00000	0.00000	0.00225	0.00004	0.01
1,995.00	0.28900	0.00161	0.00000	0.00000	0.00000	0.00002	0.00004	-
646.94	0.12495	0.00062	0.00000	0.00000	0.00000	0.00225	0.00004	0.01
1,995.00	0.28900	0.00161	0.00000	0.00000	0.00000	0.00002	0.00004	-
646.94	0.12495	0.00062	0.00000	0.00000	0.00000	0.00225	0.00004	0.01

Appendix 4 Maintenance calculating model

Table A4.1 Maintenance calculating model, reference project Hertenrade Den Haag

		Quatity	Cost/ unit	Years in which maintenance activities are planned				
				5	10	15	20	25
2A	SUBSTRUCTURE	m.i.						
2B	PRIMARY STRUCTURE	m.i.						
2C	ROOFS							
2C (27)	paintwork roof edges: overpaint system	140 m	17	2,380	2,380	2,380	2,380	
	paintwork roof edges repaint system	140 m	25					3,500
2C (37)	roof light/light strip element: sealing	3 m²	5	15	15	15	15	
	roof light/light strip element: replacement	3 m²	685					2,055
2C (47)	roof covering: replacement	613 m²	43				26,359	
	roof edges: inspection/repair	70 m	10	700	700	700		700
	joints of sheet lead 5 kg/m: replacement	20 m	200					4,000
2D	FACADES							
2D (31)	wooden window frames: inspection/repair	719 m²	10	7,190	7,190	7,190	7,190	7,190
	synthetic window frames: inspection/repair	- m²	15	-	-	-	-	-
	front door: replacement	33 units	860					28,380
	glazed door: replacement	60 units	860					51,600
	plywood door: replacement	- units	860					-
	patio door: replacement	- units	2,000					-
	opening windows: replacement	m.i.						
	double glazing: replacement	539 m²	120					64,710
	paintwork wooden frames: overpaint system	719 m²	36	25,884	25,884	25,884	25,884	
	paintwork wooden frames: repaint system	719 m²	60					43,140
2D (41)	replacement of jointing	1,826 m²	65					118,690
	paintwork on rendered facades	- m²	30			-		-
2E	INTERNAL WALLS							
2E (32)	internal doors (storage area): inspection/repair	36 units	-					
	plywood doors (storage area): replacement	36 units	860					30,960
	paintwork int.doors (storage): overpaint system	162 m²	36		5,832		5,832	
2E (42)	whitewashing internal walls of common areas	3 stairwells	3,000		9,000		9,000	
2F	FLOORS							
2F (23)	balcony edges	m.i.						
2F (43)	floor finishing of common areas	m.i.						
2G	STAIRS, RAMPS AND BALUSTRADES							
2G (34)	paintwork stairs and railings: overpaint system	3 stairwells	1,250	3,750	3,750	3,750	3,750	
	paintwork balcony railings: overpaint system	90 m	36	3,240	3,240	3,240	3,240	

		Quatity		Cost/ unit	Years in which maintenance activities are planned				
					5	10	15	20	25
2H	CEILINGS								
2H (45)	paintwork fibre-board ceiling (storage area)	500	m²	30			15,000		
	modular ceiling in common area: replacement	500	m²	42					21,000
	paintwork external ceiling: overpaint system	180	m²	36	6,480	6,480	6,480	6,480	
	paintwork external ceiling: repaint system	180	m²	60					10,800
3	SERVICES								
3A (50)	flushing sewerage system	3	stairwells	50	150	150	150	150	150
	fire booster: maintenance	3	stairwells	300	900	900	900	900	900
	central heating: maintenance (in service charges)		m.i.						
	rainwater pipes: replacement	30	apartments	10		300		300	
	central heating: replacement of boilers	30	units	2,500			75,000		
	mechanical ventilation units: replacement	30	units	600				18,000	
3B (60)	electricity meters: replacement (by energy comp.)		m.i.						
3C (66)	lifts: inspection and maintenance (in service charge)		m.i.						
	MV units of lifts: replacement	3	units	1,000		3,000		3,000	
	lift installations: replacement	3	units	70,000					210,000
4	FURNISHING								
4A (70)	sink units and sanitary fittings: replacement		m.i.						
5	EXTERNAL FINISHING								
5A (90)	pavement repair	60	m²	23		1,380		1,380	
	TOTAL IN EUROS 2004				50,689	70,201	140,689	113,860	597,775
	cost increases	2.50%	per annum		6,661	19,662	63,071	72,713	510,466
	TOTAL IN EUROS (NOMINAL COSTS)				57,350	89,863	203,760	186,573	1,108,241
	Percentage included in operation				100%	100%	100%	100%	20%
	Nominal sums included in operation				57,350	89,863	203,760	186,573	221,648
	Present Value based on discount rate:	6.00%			42,855	50,179	85,022	58,174	51,644
	Present Value of maintenance (total)								287,874
	Number of apartments calculated	30	apartments						
	Present Value of maintenance (per apartment)								9,596

Appendix 5 Development process schemes in several countries

1 The Netherlands

In the Netherlands architect's commissions are usually based upon Standard Conditions (BNA, 2002). These conditions discern a series of fixed stages and duties for an architectural development project.

- The preliminary design ('voorlopig ontwerp') comprises the development of an overall representation of the building project as for the siting, the architectural appearance, the main lay-out, the structural and constructional design and the financial aspects.
- The definite design ('definitief ontwerp') comprises the specification of the building project as for the appearance, the internal and external structure, the constructional design and financial aspects. This process stage also comprises the representation per element and per room as for the construction, materials and dimensions.
- The building preparation works ('bouwvoorbereiding') consist of the planning application and the specification of the project in such a way that this specification can form a basis for tendering and contracting. In this stage detailed building specifications and construction documents have to be made, in which definite choices for materials, finishing, details and colour.
- After these more or less design-centred stages, the pricing and contracting stage ('prijs- en contractvorming') follows and, finally, the realisation and completion ('uitvoering en oplevering') of the building.

>>

Table A5.1 Process phases and aspects in Development Cycle for low-rise

Process phases	Programming aspects	Design aspects	Estimating aspects
1. Targeting	Constraints Data Goals and objectives	Visualising of the overall ideas on the scale of the whole site	Rough estimate of overall investment costs
2. Programme	Preliminary programme	First sketches	Rough cost estimate
3. Preliminary design	More developed programme	Preliminary design	Preliminary design estimate
4. Definite design	Definite programme	Definite design	Definite design estimate
5. Specification	Building specifications	Specification drawings	Specified estimate
6. Contracting		Bidding process	Contractor's offers
7. Realisation		Construction	
		Distribution (of dwellings among applying households)	
8. Operation		Occupation	
		Evaluation	

Source: COWON, 1974

'Ontwikkelingscyclus Laagbouw', Development Cycle for Low-rise Housing (COWOM, 1974). In every phase the process is to start with the activities concerning the programming aspect of that phase. Next the resulting program has to be translated into the terms of a more or less elaborated design (according to the character of the process phase). The construction costs of this design have to be estimated and the result of this estimate is compared with the financial criteria that have been set to the project. Then the stakeholders of the project decide if the process can go on to the next phase or if they have to reconsider the premises of their program (Bouwcentrum, 1981a, 1981b and 1981c).

2 United Kingdom

The Standard Form of Agreement (RIBA, 1999) discerns the following project stages for classifying architect's design services:

- appraisal
- strategic brief
- outline proposals
- detailed proposals
- final proposals
- production information
- tender documents
- tender action
- mobilisation
- construction to practical completion
- after practical completion.

3 Germany

Honorarordnung für Architekten und Ingenieure – HOAI 2002 (Bundesregierung, 2003) discerns the following 'Leistungsphasen' for building development processes:

■ program phase	'Grundlagenermittlung'
■ pre-design phase	'Vorplanung'
■ design phase	'Entwurfsplanung'
■ permits planning phase	'Genehmigungsplanung'
■ building preparation	'Ausfürungsplanung'
■ preparing biddings and contract	'Vorbereitung der Vergabe'
■ assisting to biddings and contract	'Mitwirken bei der Vergabe'
■ controlling construction	'Objektüberwachung'
■ completion and documentation	'Objektbetreuung/Dokumentation'

4 USA

In the United States of America the Local Initiatives Support Corporation is recommending, on the website www.designadvisor.org a structured approach for affordable housing project development (LISC, 2003).

In the Design Advisor the following phases (and activities) are discerned:

- Concept phase – This phase comprises a 'site analysis' and 'pre-design' activities, like programming, making space schematics, flow diagrams and surveys of existing facilities.
- Predevelopment phase – In this phase an 'early schematic design' is composed.
- Development phase – This phase consists of making a 'later schematic design', followed by the 'design development', the 'contract documents' and the 'bidding or negotiations'.

Appendix 6 Cost and eco-cost estimates of a case study

Table A6.1 General project data and survey of traditional construction costs of refurbishment of 50 apartments + lift at Nijmegen (per apartment), reference date 01-01-2004

Year of refurbishment: 2001/2002 — construction costs
Number of dwellings: 50 (part of larger project)
Other purposes: n.a.
Number of floors: 8
Area built on: 553 m²
Useable floor area: 2,886 m²
Gross floor area: 4,338 m²
Gross contents: 12,441 m³

SUBSTRUCTURE: pile foundation, no measures
PRIMARY STRUCTURE: concrete walls, floors and roof-structure; adaptation related to lift replacement
ROOFS: adaptation of roof edges and partial replacement of bituminous roof covering related to lift replacement
FACADES: replacement of windows, removal of asbestos cladding, application of external wall insulation
INTERNAL WALLS: maintenance of interior wall finishing and internal doors
FLOORS: repair and extension of balconies
STAIRS: resetting escape stairs and cleaning of stairwells
CEILINGS: replacement of ceilings in common areas
SERVICES, FURNISHINGS, FITTINGS: adaptation of HVAC, electric systems and replacement of lift

Direct construction costs		25,642
Building site costs	19,3%	4,952
		30,594
Overheads building company	7%	2,142
		32,736
Allowance for profit	4%	1,309
Construction costs (VAT excluded)		34,045
VAT	19%	6,469
Construction costs (VAT included)		40,514

				exclusive of VAT	inclusive of VAT
Construction costs per m² UFA	57	m²	net residential	594	707
Construction costs per m² UFA		m²	residential + parking		
Construction costs per m² GFA	87	m²		392	467
Construction costs per m³ GC	249	m³		137	163

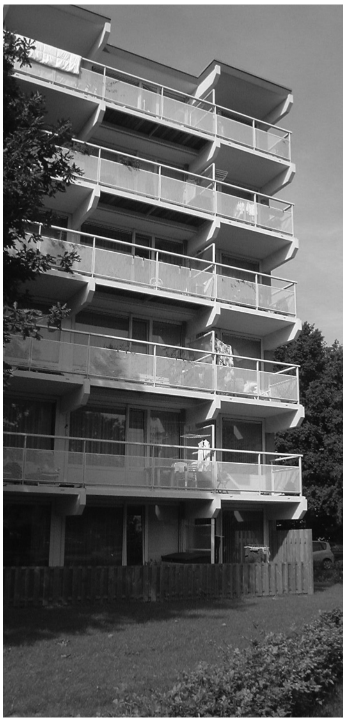


Table A6.2 Estimate according to NEN 2634 level 3 of traditional construction costs of refurbishment of 50 apartments + lift at Nijmegen (per apartment), reference date 01-01-2004

			Quantity		Construction costs in euro	
					per unit	total
2.A		**Substructure**				
	(11)	Excavation	11.09	m²	-	-
	(13)	Floor beds	0.48	m²	-	-
	(16)	Foundations	11.09	m²	-	-
	(17)	Pile Foundations	11.09	m²	-	-
						-
2.B		**Primary Structure**				
	(21)	External walls	22.68	m²	4	88
	(22)	Internal walls	39.59	m²	0	7
	(23)	Floors and galleries	80.48	m²	1	41
	(27)	Roofs	11.45	m²	6	67
	(28)	Frames	87.00	m²	0	15
						218
2.C		**Roofs (secondary structure/finishing)**				
	(27)	Roofs	12.76	m²	8	107
	(37)	Roof openings	-	m²	-	-
	(47)	Roof finishes	12.76	m²	3	39
						146
2.D		**Facades (secondary structure/finishing)**				
	(21)	External walls	34.64	m²	0	5
	(31)	External wall openings	22.92	m²	358	8,205
	(41)	External wall finishes	34.64	m²	111	3,841
						12,051
2.E		**Internal walls (secondary structure/finishing)**				
	(22)	Internal walls	54.19	m²	4	205
	(32)	Internal wall openings	18.91	m²	53	996
	(42)	Internal wall finishes	210.26	m²	3	532
						1,733
2.F		**Floors (secondary structure/finishing)**				
	(23)	Floors and galleries	13.86	m²	132	1,824
	(33)	Floor openings	3.27	m²	-	-
	(43)	Floor finishes	94.82	m²	6	597
						2,421
2.G		**Stairs. ramps and balustrades**				
	(24)	Stairs and ramps	0.22	p	86	19
	(34)	Balustrades	12.07	m	206	2,487
	(44)	Stair finishes	0.22	p	535	118
						2,624
2.H		**Ceilings (indoor and outdoor)**				
	(45)	Ceiling finishes	81.32	m²	3	207
						207

			Quantity		Construction costs in euro per unit	total
3.A		**Mechanical services**				
	(51)	Heat generation	87.00	m²	3	242
	(52)	Drainage	87.00	m²	3	229
	(53)	Hot and cold water	87.00	m²	-	-
	(54)	Gasses	87.00	m²	-	-
	(55)	Refrigeration	87.00	m²	-	-
	(56)	Space heating/distribution	87.00	m²	-	-
	(57)	Ventilation and air conditioning	87.00	m²	6	564
	(58)	Air conditioning system	87.00	m²	-	-
						1,035
3.B		**Electrical services**				
	(61)	Common facilities	87.00	m²	10	877
	(62)	Power	87.00	m²	-	-
	(63)	Lighting	87.00	m²	1	58
	(64)	Communications	87.00	m²	-	-
	(65)	Security	87.00	m²	1	65
	(68)	Building management system	87.00	m²	-	-
						1,000
3.C		**Lift and transport**				
	(66)	Lift and transport	0.04	p	71.000	2,848
						2,848
4.A		**Furnishings, fittings**				
	(71)	Circulation	87.00	m²	1	110
	(72)	General room	87.00	m²	-	-
	(73)	Culinary	87.00	m²	8	701
	(74)	Sanitary	87.00	m²	1	118
	(75)	Cleaning	87.00	m²	-	-
	(76)	Storage	87.00	m²	-	-
						929
5.		**External structures and finishing**				
	(90)	External structures and finishing	116.70	m²	1	171
						171
6.A		**Sundries**				
	(99)	Sundries	43.50	m²	6	256
						256
		Total of direct construction costs	**87.00**	**m²**	**295**	**25,642**
6.U		**General building costs and surcharges**				
	(--)	Building site costs	0.02	proj	246,916	4,952
						4,952

Table A6.3 General project data and survey of eco-costs of refurbishment of 50 apartments + lift at Nijmegen (per apartment), reference date 01-01-2004

Year of refurbishment: 2001/2002 — Eco-costs
Number of dwellings: 50 (part of larger project)
Other purposes: n.a.
Number of floors: 8
Area built on: 553 m²
Useable floor area: 2,886 m²
Gross floor area: 4,338 m²
Gross contents: 12,441 m³

SUBSTRUCTURE: pile foundation, no measures
PRIMARY STRUCTURE: concrete walls, floors and roof-structure; adaptation related to lift replacement
ROOFS: adaptation of roof edges and partial replacement of bituminous roof covering related to lift replacement
FACADES: replacement of windows, removal of asbestos cladding, application of external wall insulation
INTERNAL WALLS: maintenance of interior wall finishing and internal doors
FLOORS: repair and extension of balconies
STAIRS: resetting escape stairs and cleaning of stairwells
CEILINGS: replacement of ceilings in common areas
SERVICES, FURNISHINGS, FITTINGS: adaptation of HVAC, electric systems and replacement of lift

Direct construction costs		7,197
Building site costs	12,7%	911
		8,108
Overheads building company	3,7%	300
		8,408
Allowance for profit		0
Construction costs (VAT excluded)		8,408
VAT	19%	1,597
Construction costs (VAT included)		10.005

				exclusive of VAT	inclusive of VAT
Construction costs per m² UFA	57	m²	net residential	147	175
Construction costs per m² UFA		m²	residential + parking		
Construction costs per m² GFA	87	m²		97	115
Construction costs per m³ GC	249	m³		34	40

Table A6.4 Estimate according to NEN 2634 level 3 of eco-costs of refurbishment of 50 apartments + lift at Nijmegen (per apartment), reference date 01-01-2004

			Quantity		Eco-costs in euro per unit	Eco-costs in euro total
2.A		**Substructure**				
	(11)	Excavation	11.09	m^2	-	-
	(13)	Floor beds	0.48	m^2	-	-
	(16)	Foundations	11.09	m^2	-	-
	(17)	Pile Foundations	11.09	m^2	-	-
						-
2.B		**Primary Structure**				
	(21)	External walls	22.68	m^2	1	15
	(22)	Internal walls	39.59	m^2	0	1
	(23)	Floors and galleries	80.48	m^2	0	10
	(27)	Roofs	11.45	m^2	1	13
	(28)	Frames	87.00	m^2	0	2
						41
2.C		**Roofs (secondary structure/finishing)**				
	(27)	Roofs	12.76	m^2	3	35
	(37)	Roof openings	-	m^2	-	-
	(47)	Roof finishes	12.76	m^2	1	9
						44
2.D		**Facades (secondary structure/finishing)**				
	(21)	External walls	34.64	m^2	0	1
	(31)	External wall openings	22.92	m^2	105	2,417
	(41)	External wall finishes	34.64	m^2	26	904
						3,322
2.E		**Internal walls (secondary structure/finishing)**				
	(22)	Internal walls	54.19	m^2	1	36
	(32)	Internal wall openings	18.91	m^2	6	120
	(42)	Internal wall finishes	210.26	m^2	1	110
						266
2.F		**Floors (secondary structure/finishing)**				
	(23)	Floors and galleries	13.86	m^2	127	1,753
	(33)	Floor openings	3.27	m^2	-	-
	(43)	Floor finishes	94.82	m^2	1	102
						1,855
2.G		**Stairs. ramps and balustrades**				
	(24)	Stairs and ramps	0.22	p	29	6
	(34)	Balustrades	12.07	m	29	348
	(44)	Stair finishes	0.22	p	73	16
						370
2.H		**Ceilings (indoor and outdoor)**				
	(45)	Ceiling finishes	81.32	m^2	0	29
						29

					Eco-costs in euro	
			Quantity		per unit	total
3.A		**Mechanical services**				
	(51)	Heat generation	87.00	m²	0	40
	(52)	Drainage	87.00	m²	1	60
	(53)	Hot and cold water	87.00	m²	-	-
	(54)	Gasses	87.00	m²	-	-
	(55)	Refrigeration	87.00	m²	-	-
	(56)	Space heating/distribution	87.00	m²	-	-
	(57)	Ventilation and air conditioning	87.00	m²	2	155
	(58)	Air conditioning system	87.00	m²	-	-
						255
3.B		**Electrical services**				
	(61)	Common facilities	87.00	m²	3	219
	(62)	Power	87.00	m²	-	-
	(63)	Lighting	87.00	m²	0	14
	(64)	Communications	87.00	m²	-	-
	(65)	Security	87.00	m²	0	16
	(68)	Building management system	87.00	m²	-	-
						249
3.C		**Lift and transport**				
	(66)	Lift and transport	0.04	p	14.911	598
						598
4.A		**Furnishings, fittings**				
	(71)	Circulation	87.00	m²	0	8
	(72)	General room	87.00	m²	-	-
	(73)	Culinary	87.00	m²	1	46
	(74)	Sanitary	87.00	m²	0	37
	(75)	Cleaning	87.00	m²	-	-
	(76)	Storage	87.00	m²	-	-
						91
5.		**External structures and finishing**				
	(90)	External structures and finishing	116.70	m²	0	29
						29
6.A		**Sundries**				
	(99)	Sundries	43.50	m²	1	48
						48
		Total of direct construction costs	**87.00**	**m²**	**83**	**7,197**
6.U		**General building costs and surcharges**				
	(--)	Building site costs	0.02	proj	45.401	911
						911

Table A6.5 General project data and survey of traditional construction costs of extensive renovation of 30 apartments + lift at Nijmegen (per apartment), reference date 01-01-2004

Year of renovation: 2001/2002 — construction costs
Number of dwellings after joining: 30 (part of larger project)
Other purposes: n.a.
Number of floors: 7
Area built on: 557 m²
Useable floor area: 2,480 m²
Gross floor area: 3,796 m²
Gross contents: 10,923 m³

SUBSTRUCTURE: pile foundation, no measures
PRIMARY STRUCTURE: concrete walls, floors, roof-structure; adaptation related to lift replacement and joining of apartments
ROOFS: adaptation of roof edges and partial replacement of bituminous roof covering related to lift replacement
FACADES: replacement of windows, removal of asbestos cladding, application of external wall insulation
INTERNAL WALLS: general change in layout, separation walls of plaster blocks, rebated doors in steel frames
FLOORS: repair and extension of balconies
STAIRS: resetting escape stairs and cleaning of stairwells
CEILINGS: replacement of ceilings in common areas, new plasterboard ceilings in apartments
SERVICES, FURNISHINGS, FITTINGS: replacement of HVAC, electric systems and lift

Direct construction costs		70,322
Building site costs	11,4%	7,979
		78,301
Overheads building company	7%	5,481
		83,782
Allowance for profit	4%	3,351
Construction costs (VAT excluded)		87,133
VAT	19%	16,555
Construction costs (VAT included)		103,688

				exclusive of VAT	inclusive of VAT
Construction costs per m² UFA	83	m²	net residential	1,054	1,254
Construction costs per m² UFA		m²	residential + parking		
Construction costs per m² GFA	127	m²		689	819
Construction costs per m³ GC	364	m³		239	285

Table A6.6 Estimate according to NEN 2634 level 3 of traditional construction costs of extensive renovation of 30 apartments + lift at Nijmegen (per apartment), reference date 01-01-2004

			Quantity		Construction costs in euro per unit	total
2.A		**Substructure**				
	(11)	Excavation	18.50	m²	-	-
	(13)	Floor beds	0.80	m²	-	-
	(16)	Foundations	18.50	m²	-	-
	(17)	Pile Foundations	18.50	m²	-	-
						-
2.B		**Primary Structure**				
	(21)	External walls	38.31	m²	5	190
	(22)	Internal walls	60.42	m²	3	180
	(23)	Floors and galleries	117.36	m²	1	69
	(27)	Roofs	19.10	m²	6	117
	(28)	Frames	127.00	m²	0	25
						581
2.C		**Roofs (secondary structure/finishing)**				
	(27)	Roofs	19.10	m²	9	179
	(37)	Roof openings	-	m²	-	-
	(47)	Roof finishes	19.10	m²	3	65
						244
2.D		**Facades (secondary structure/finishing)**				
	(21)	External walls	51.02	m²	2	82
	(31)	External wall openings	33.62	m²	413	13,892
	(41)	External wall finishes	51.02	m²	113	5,761
						19,735
2.E		**Internal walls (secondary structure/finishing)**				
	(22)	Internal walls	72.13	m²	64	4,618
	(32)	Internal wall openings	22.72	m²	203	4,607
	(42)	Internal wall finishes	304.05	m²	18	5,417
						14,642
2.F		**Floors (secondary structure/finishing)**				
	(23)	Floors and galleries	19.81	m²	256	5,061
	(33)	Floor openings	4.82	m²	-	-
	(43)	Floor finishes	138.01	m²	29	3,958
						9,019
2.G		**Stairs. ramps and balustrades**				
	(24)	Stairs and ramps	0.33	p	95	32
	(34)	Balustrades	16.96	m	203	3,448
	(44)	Stair finishes	0.33	p	521	174
						3,654
2.H		**Ceilings (indoor and outdoor)**				
	(45)	Ceiling finishes	118.67	m²	17	2,003
						2,003

			Quantity		Construction costs in euro per unit	total
3.A		**Mechanical services**				
	(51)	Heat generation	127.00	m²	35	4.437
	(52)	Drainage	127.00	m²	8	984
	(53)	Hot and cold water	127.00	m²	7	896
	(54)	Gasses	127.00	m²	3	320
	(55)	Refrigeration	127.00	m²	-	-
	(56)	Space heating/distribution	127.00	m²	-	-
	(57)	Ventilation and air conditioning	127.00	m²	6	706
	(58)	Air conditioning system	127.00	m²	-	-
						7,343
3.B		**Electrical services**				
	(61)	Common facilities	127.00	m²	7	908
	(62)	Power	127.00	m²	-	-
	(63)	Lighting	127.00	m²	27	3,401
	(64)	Communications	127.00	m²	9	1,145
	(65)	Security	127.00	m²	1	96
	(68)	Building management system	127.00	m²	-	-
						5,550
3.C		**Lift and transport**				
	(66)	Lift and transport	0.07	p	63.000	4,215
						4,215
4.A		**Furnishings, fittings**				
	(71)	Circulation	127.00	m²	1	114
	(72)	General room	127.00	m²	-	-
	(73)	Culinary	127.00	m²	7	947
	(74)	Sanitary	127.00	m²	10	1,256
	(75)	Cleaning	127.00	m²	-	-
	(76)	Storage	127.00	m²	-	-
						2,317
5.		**External structures and finishing**				
	(90)	External structures and finishing	120.71	m²	2	271
						271
6.A		**Sundries**				
	(99)	Sundries	127.00	m²	6	747
						747
		Total of direct construction costs	**127.00**	**m²**	**554**	**70,322**
6.U		**General building costs and surcharges**				
	(--)	Building site costs	0.03	proj	238.487	7,979
						7,979

Table A6.7 General project data and survey of eco-costs of extensive renovation of 30 apartments + lift at Nijmegen (per apartment), reference date 01-01-2004

Year of renovation: 2001/2002 — Eco-costs
Number of dwellings after joining: 30 (part of larger project)
Other purposes: n.a.
Number of floors: 7
Area built on: 557 m²
Useable floor area: 2,480 m²
Gross floor area: 3,796 m²
Gross contents: 10,923 m³

SUBSTRUCTURE: pile foundation, no measures
PRIMARY STRUCTURE: concrete walls, floors, roof-structure; adaptation related to lift replacement and joining of apartments
ROOFS: adaptation of roof edges and partial replacement of bituminous roof covering related to lift replacement
FACADES: replacement of windows, removal of asbestos cladding, application of external wall insulation
INTERNAL WALLS: general change in layout, separation walls of plaster blocks, rebated doors in steel frames
FLOORS: repair and extension of balconies
STAIRS: resetting escape stairs and cleaning of stairwells
CEILINGS: replacement of ceilings in common areas, new plasterboard ceilings in apartments
SERVICES, FURNISHINGS, FITTINGS: replacement of HVAC, electric systems and lift

Direct construction costs		17,409
Building site costs	8,5%	1,474
		18,884
Overheads building company	4,1%	767
		19,651
Allowance for profit		
Construction costs (VAT excluded)		19,651
VAT	19%	3,734
Construction costs (VAT included)		23,384

				exclusive of VAT	inclusive of VAT
Construction costs per m² UFA	83	m²	net residential	238	283
Construction costs per m² UFA		m²	residential + parking		
Construction costs per m² GFA	127	m²		155	185
Construction costs per m³ GC	364	m³		54	64

Table A6.8 Estimate according to NEN 2634 level 3 of eco-costs of extensive renovation of 30 apartments + lift at Nijmegen (per apartment, reference date 01-01-2004)

			Quantity		Eco-costs in euro per unit	Eco-costs in euro total
2.A		**Substructure**				
	(11)	Excavation	18.50	m²	-	-
	(13)	Floor beds	0.80	m²	-	-
	(16)	Foundations	18.50	m²	-	-
	(17)	Pile Foundations	18.50	m²	-	-
						-
2.B		**Primary Structure**				
	(21)	External walls	38.31	m²	1	33
	(22)	Internal walls	60.42	m²	0	22
	(23)	Floors and galleries	117.36	m²	0	17
	(27)	Roofs	19.10	m²	1	23
	(28)	Frames	127.00	m²	0	3
						98
2.C		**Roofs (secondary structure/finishing)**				
	(27)	Roofs	19.10	m²	3	58
	(37)	Roof openings	-	m²	-	-
	(47)	Roof finishes	19.10	m²	1	14
						72
2.D		**Facades (secondary structure/finishing)**				
	(21)	External walls	51.02	m²	1	30
	(31)	External wall openings	33.62	m²	124	4,168
	(41)	External wall finishes	51.02	m²	26	1,347
						5,545
2.E		**Internal walls (secondary structure/finishing)**				
	(22)	Internal walls	72.13	m²	10	736
	(32)	Internal wall openings	22.72	m²	29	661
	(42)	Internal wall finishes	304.05	m²	4	1,108
						2,505
2.F		**Floors (secondary structure/finishing)**				
	(23)	Floors and galleries	19.81	m²	142	2,814
	(33)	Floor openings	4.82	m²	-	-
	(43)	Floor finishes	138.01	m²	6	885
						3,699
2.G		**Stairs. ramps and balustrades**				
	(24)	Stairs and ramps	0.33	p	32	11
	(34)	Balustrades	16.96	m	29	497
	(44)	Stair finishes	0.33	p	72	24
						532
2.H		**Ceilings (indoor and outdoor)**				
	(45)	Ceiling finishes	118.67	m²	3	321
						321

			Quantity		Eco-costs in euro per unit	Eco-costs in euro total
3.A		**Mechanical services**				
	(51)	Heat generation	127.00	m²	8	979
	(52)	Drainage	127.00	m²	1	188
	(53)	Hot and cold water	127.00	m²	2	313
	(54)	Gasses	127.00	m²	0	49
	(55)	Refrigeration	127.00	m²	-	-
	(56)	Space heating/distribution	127.00	m²	-	-
	(57)	Ventilation and air conditioning	127.00	m²	2	226
	(58)	Air conditioning system	127.00	m²	-	-
						1,755
3.B		**Electrical services**				
	(61)	Common facilities	127.00	m²	2	227
	(62)	Power	127.00	m²	-	-
	(63)	Lighting	127.00	m²	8	955
	(64)	Communications	127.00	m²	2	290
	(65)	Security	127.00	m²	0	24
	(68)	Building management system	127.00	m²	-	-
						1,496
3.C		**Lift and transport**				
	(66)	Lift and transport	0.07	p	13.231	885
						885
4.A		**Furnishings, fittings**				
	(71)	Circulation	127.00	m²	0	8
	(72)	General room	127.00	m²	-	-
	(73)	Culinary	127.00	m²	1	70
	(74)	Sanitary	127.00	m²	2	238
	(75)	Cleaning	127.00	m²	-	-
	(76)	Storage	127.00	m²	-	-
						316
5.		**External structures and finishing**				
	(90)	External structures and finishing	120.71	m²	0	46
						46
6.A		**Sundries**				
	(99)	Sundries	127.00	m²	1	141
						141
		Total of direct construction costs	**127.00**	**m²**	**137**	**17,409**
6.U		**General building costs and surcharges**				
	(--)	Building site costs	0.03	proj	44.068	1,474
						1,474

Table A6.9 General project data and survey of traditional construction costs of new building of 37 apartments + parking basement at Venray (per apartment), reference date 01-01-2004

Year of construction: 1999 — construction costs
Number of dwellings: 37
Other purposes: 1,211 m² parking basement
Number of floors: 5 + parking basement
Area built on: 1,211 m²
Useable floor area: 3,767 m²
Gross floor area: 5,728 m²
Gross contents: 16,667 m³

SUBSTRUCTURE: pile foundation, concrete ground beams, concrete floor with monolithic finish
PRIMARY STRUCTURE: concrete walls, wide-slab floors and roof-structure
ROOFS: timber eaves, canopy of aluminium slats, bituminous roof covering, concrete tiles on roof terrace
FACADES: brickwork outer cavity leaf, timber cladding, (high-efficiency) double glazing set in wooden frames
INTERNAL WALLS: separation walls of cellular concrete, sand-lime blocks and brickwork, rebated doors in steel frames
FLOORS: prefab concrete galleries, cement mortar screeds, hard-burnt floor tiles
STAIRS: prefab concrete stairs, steel escape stairs, timber stairs, concrete ramp to basement
CEILINGS: spray-on plaster, ceiling system panels, marine ply outdoor ceiling
SERVICES, FURNISHINGS, FITTINGS: standard quality, 1 lift

Direct construction costs		91,071
Building site costs	7,2%	6,587
		97,658
Overheads building company	7%	6,836
		104,494
Allowance for profit	4%	4,180
Construction costs (VAT excluded)		108,674
VAT	19%	20,648
Construction costs (VAT included)		129,322

				exclusive of VAT	inclusive of VAT
Construction costs per m² UFA	102	m²	net residential	1,067	1,270
Construction costs per m² UFA	123	m²	residential + parking	884	1,051
Construction costs per m² GFA	155	m²		702	835
Construction costs per m³ GC	450	m³		241	287

Table A6.10 Estimate according to NEN 2634 level 3 of traditional construction costs of a new building of 37 apartments + parking basement at Venray (per apartment), reference date 01-01-2004

					Construction costs in euro	
			Quantity		per unit	total
2.A		**Substructure**				
	(11)	Excavation	32.25	m²	42	1,364
	(13)	Floor beds	32.25	m²	70	2,265
	(16)	Foundations	32.25	m²	54	1,755
	(17)	Pile Foundations	32.25	m²	34	1,083
						6,467
2.B		**Primary Structure**				
	(21)	External walls	33.95	m²	87	2,962
	(22)	Internal walls	54.33	m²	82	4,481
	(23)	Floors and galleries	118.11	m²	57	6,773
	(27)	Roofs	29.18	m²	56	1,648
	(28)	Frames	154.60	m²	22	3,370
						19,234
2.C		**Roofs (secondary structure/finishing)**				
	(27)	Roofs	35.81	m²	67	2,385
	(37)	Roof openings	-	m²	-	-
	(47)	Roof finishes	35.81	m²	38	1,358
						3,743
2.D		**Facades (secondary structure/finishing)**				
	(21)	External walls	64.26	m²	109	6,993
	(31)	External wall openings	43.67	m²	334	14,580
	(41)	External wall finishes	64.26	m²	-	-
						21,573
2.E		**Internal walls (secondary structure/finishing)**				
	(22)	Internal walls	88.15	m²	66	5,851
	(32)	Internal wall openings	24.83	m²	66	1,648
	(42)	Internal wall finishes	349.22	m²	6	1,984
						9,483
2.F		**Floors (secondary structure/finishing)**				
	(23)	Floors and galleries	15.79	m²	245	3,863
	(33)	Floor openings	3.24	m²	25	83
	(43)	Floor finishes	163.93	m²	17	2,758
						6,704
2.G		**Stairs. ramps and balustrades**				
	(24)	Stairs and ramps	0.94	p	1.880	1,776
	(34)	Balustrades	7.56	m	147	1,110
	(44)	Stair finishes	0.94	p	-	-
						2,886
2.H		**Ceilings (indoor and outdoor)**				
	(45)	Ceiling finishes	147.28	m²	14	2,071
						2,071

			Quantity		Construction costs in euro per unit	total
3.A		**Mechanical services**				
	(51)	Heat generation	154.60	m²	23	3,550
	(52)	Drainage	154.60	m²	4	695
	(53)	Hot and cold water	154.60	m²	8	1,182
	(54)	Gasses	154.60	m²	1	208
	(55)	Refrigeration	154.60	m²	-	-
	(56)	Space heating/distribution	154.60	m²	-	-
	(57)	Ventilation and air conditioning	154.60	m²	10	1,515
	(58)	Air conditioning system	154.60	m²	-	-
						7,150
3.B		**Electrical services**				
	(61)	Common facilities	154.60	m²	-	-
	(62)	Power	154.60	m²	0	65
	(63)	Lighting	154.60	m²	20	3,080
	(64)	Communications	154.60	m²	2	235
	(65)	Security	154.60	m²	2	314
	(68)	Building management system	154.60	m²	-	-
						3,694
3.C		**Lift and transport**				
	(66)	Lift and transport	0.03	p	52.500	1,417
						1,417
4.A		**Furnishings, fittings**				
	(71)	Circulation	154.60	m²	1	110
	(72)	General room	154.60	m²	-	-
	(73)	Culinary	154.60	m²	18	2,844
	(74)	Sanitary	154.60	m²	15	2,281
	(75)	Cleaning	154.60	m²	-	-
	(76)	Storage	154.60	m²	-	-
						5,235
5.		**External structures and finishing**				
	(90)	External structures and finishing	101.35	m²	5	507
						507
6.A		**Sundries**				
	(99)	Sundries	154.60	m²	6	909
						909
		Total of direct construction costs	154.60	m²	588	**91,071**
6.U		**General building costs and surcharges**				
	(--)	Building site costs	0.03	proj	244.062	6,587
						6,587

Table A6.11 General project data and survey of eco-costs of a new buiding of 37 apartments + parking basement at Venray (per apartment), reference date 01-01-2004

Year of construction: 1999 — Eco-costs
Number of dwellings: 37
Other purposes: 1,211 m² parking basement
Number of floors: 5 + parking basement
Area built on: 1,211 m²
Useable floor area: 3,767 m²
Gross floor area: 5,728 m²
Gross contents: 16,667 m³

SUBSTRUCTURE: pile foundation, concrete ground beams, concrete floor with monolithic finish
PRIMARY STRUCTURE: concrete walls, wide-slab floors and roof-structure
ROOFS: timber eaves, canopy of aluminium slats, bituminous roof covering, concrete tiles on roof terrace
FACADES: brickwork outer cavity leaf, timber cladding, (high-efficiency) double glazing set in wooden frames
INTERNAL WALLS: separation walls of cellular concrete, sand-lime blocks and brickwork, rebated doors in steel frames
FLOORS: prefab concrete galleries, cement mortar screeds, hard-burnt floor tiles
STAIRS: prefab concrete stairs, steel escape stairs, timber stairs, concrete ramp to basement
CEILINGS: spray-on plaster, ceiling system panels, marine ply outdoor ceiling
SERVICES, FURNISHINGS, FITTINGS: standard quality, 1 lift

Direct construction costs		51,943
Building site costs	2,2%	1,134
		53,077
Overheads building company	1,8%	957
		54,034
Allowance for profit		0
Construction costs (VAT excluded)		54,034
VAT	19%	10,266
Construction costs (VAT included)		64,301

				exclusive of VAT	inclusive of VAT
Construction costs per m² UFA	102	m²	net residential	531	632
Construction costs per m² UFA	123	m²	residential + parking	438	521
Construction costs per m² GFA	155	m²		349	415
Construction costs per m³ GC	450	m³		120	143

Table A6.12 Estimate according to NEN 2634 level 3 of eco-costs of a new building of 37 apartments + parking basement at Venray (per apartment), reference date 01-01-2004

			Quantity		Eco-costs in euro per unit	Eco-costs in euro total
2.A		**Substructure**				
	(11)	Excavation	32.25	m²	8	250
	(13)	Floor beds	32.25	m²	109	3,517
	(16)	Foundations	32.25	m²	43	1,396
	(17)	Pile Foundations	32.25	m²	32	1,029
						6,192
2.B		**Primary Structure**				
	(21)	External walls	33.95	m²	121	4,095
	(22)	Internal walls	54.33	m²	132	7,188
	(23)	Floors and galleries	118.11	m²	70	8,225
	(27)	Roofs	29.18	m²	68	1,982
	(28)	Frames	154.60	m²	10	1,611
						23,101
2.C		**Roofs (secondary structure/finishing)**				
	(27)	Roofs	35.81	m²	14	490
	(37)	Roof openings	-	m²	-	-
	(47)	Roof finishes	35.81	m²	26	939
						1,429
2.D		**Facades (secondary structure/finishing)**				
	(21)	External walls	64.26	m²	23	1,479
	(31)	External wall openings	43.67	m²	201	8,787
	(41)	External wall finishes	64.26	m²	-	-
						10,266
2.E		**Internal walls (secondary structure/finishing)**				
	(22)	Internal walls	88.15	m²	12	1,032
	(32)	Internal wall openings	24.83	m²	8	200
	(42)	Internal wall finishes	349.22	m²	2	667
						1,899
2.F		**Floors (secondary structure/finishing)**				
	(23)	Floors and galleries	15.79	m²	107	1,692
	(33)	Floor openings	3.24	m²	14	45
	(43)	Floor finishes	163.93	m²	5	819
						2,556
2.G		**Stairs. ramps and balustrades**				
	(24)	Stairs and ramps	0.94	p	1.651	1,560
	(34)	Balustrades	7.56	m	31	232
	(44)	Stair finishes	0.94	p	-	-
						1,792
2.H		**Ceilings (indoor and outdoor)**				
	(45)	Ceiling finishes	147.28	m²	5	675
						675

				Eco-costs in euro	
		Quantity		per unit	total
3.A		**Mechanical services**			
(51)	Heat generation	154.60	m²	5	812
(52)	Drainage	154.60	m²	1	129
(53)	Hot and cold water	154.60	m²	3	449
(54)	Gasses	154.60	m²	-	33
(55)	Refrigeration	154.60	m²	-	-
(56)	Space heating/distribution	154.60	m²	-	-
(57)	Ventilation and air conditioning	154.60	m²	4	603
(58)	Air conditioning system	154.60	m²	-	-
					2,026
3.B	**Electrical services**				
(61)	Common facilities	154.60	m²	-	-
(62)	Power	154.60	m²	0	16
(63)	Lighting	154.60	m²	5	736
(64)	Communications	154.60	m²	0	44
(65)	Security	154.60	m²	1	79
(68)	Building management system	154.60	m²	-	-
					875
3.C	**Lift and transport**				
(66)	Lift and transport	0.03	p	11.026	298
					298
4.A	**Furnishings, fittings**				
(71)	Circulation	154.60	m²	0	8
(72)	General room	154.60	m²	-	-
(73)	Culinary	154.60	m²	0	40
(74)	Sanitary	154.60	m²	2	325
(75)	Cleaning	154.60	m²	-	-
(76)	Storage	154.60	m²	-	-
					373
5.	**External structures and finishing**				
(90)	External structures and finishing	101.35	m²	3	289
					289
6.A	**Sundries**				
(99)	Sundries	154.60	m²	1	172
					172
	Total of direct construction costs	**154.60**	**m²**	**335**	**51,943**
6.U	**General building costs and surcharges**				
(--)	Building site costs	0.03	proj	37.800	1,134
					1,134

Curriculum Vitae

Private data
Born 1951-06-20, nationality Dutch, married, 3 children

Education

1969	Gymnasium B, Enschede
1978	Delft University of Technology, Architecture and Housing, Master of Science

Career

1974-1975 Municipal Public Works Department of Woerden
- Assistant project manager in a municipal renovation project

1976-1986 Rotterdam Bouwcentrum
- Researcher and consultant involved in housing, mainly related to construction costs and economics
- Head of the Construction Costs department of the Housing Group of Bouwcentrum

1986-present Winket voor de bouw, construction costs consultancy
- Owner/managing director
- Special assignments:
  - Research and consultancy related to construction costs in the context of the Dutch National Housing Quality Survey (KWR)
  - Cost consultancy in design and development projects, commissioned by several architects, municipalities, housing associations and the Government Building Agency
  - Research on construction costs in health care accommodation projects, commissioned by the Netherlands Board for Hospital Facilities (CBZ)
  - Development and production of the Winket Reference Projects Model, used by a growing number of architectural firms

1996-present Delft University of Technology, Faculty of Architecture
- Assistant Professor of Housing, mission: construction costs and operating costs, especially focussed on housing

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Honorary positions

1993-1997	Member of the General Board of the Netherlands Association of Construction Economists (NVBK)
1996-1998	Member of the Editiorial Committee of Bouwmarkt (monthly magazine for prices, indices and analyses)
1998-present	Member of the Editiorial Committee of Bouwkostenkunde & Huisvestingseconomie (quarterly magazine of the NVBK)
1999-present	Member of the Executive Committee and Treasurer of the association Forum voor Volkshuisvesting (Forum for Housing)

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   www.library.tudelft.nl/ned/publiceren.