

Cost Effectiveness of Sustainable Housing Investments

Tim de Jonge

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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 starts 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 specialized 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, BUWAL 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 summarized in the following statements, which are valid simultaneously:

1. Value of houses is determined by (discounted cash flow of) future profits.
2. Value of houses is related to the (actual) all-in building costs of houses.
3. Value of houses is related to desirable characteristics / performance.
4. Value of houses is gradually diminishing due to innovations.
5. Value of houses is fluctuating by a combination of maintenance and loss of performance.
6. Value of houses is related to their location in the context of trade-offs based on status and the social acceptability of dwelling quality.
7. 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 to 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 experiences 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:

1. They are unable to communicate relevant eco-cost information, since the raw data on this subject are not readily available.
2. 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.
3. 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 neither 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, 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 m² 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/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/her own portfolio.

In estimating two exceptions can be discerned on this rule:

1. The architect is confronted with a commission referring to a category of buildings he/she is not acquainted with.
2. 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 realized 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 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.

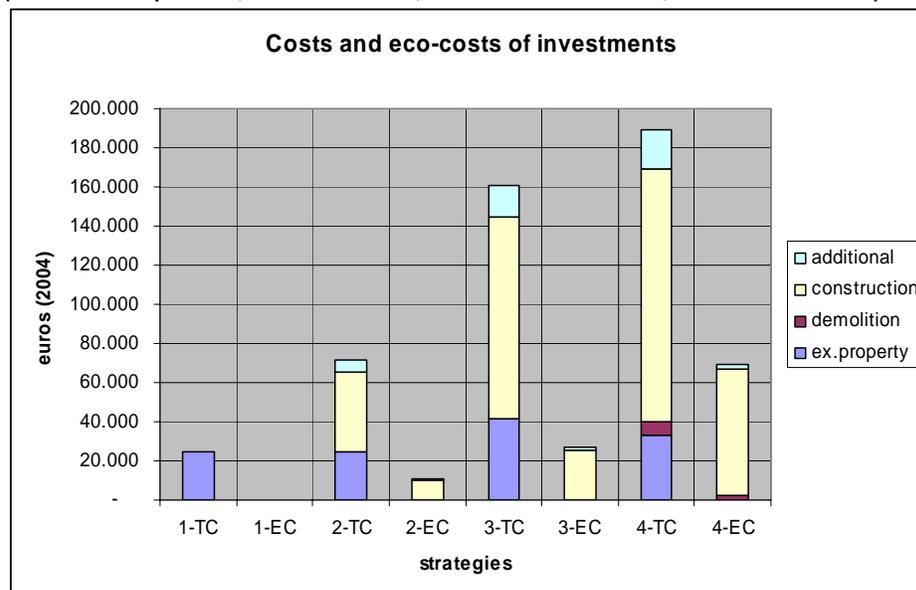
Analysis of the calculation results also indicates that the greater part of the eco-costs of buildings in the production phase can be traced back to a relatively small group of materials.

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 graph A as traditional costs and eco-costs per apartment.

Graph A: Traditional costs and eco-costs of investments at several strategies (1. continued operation, 2. refurbishment, 3. extensive renovation, 4. new construction)



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.

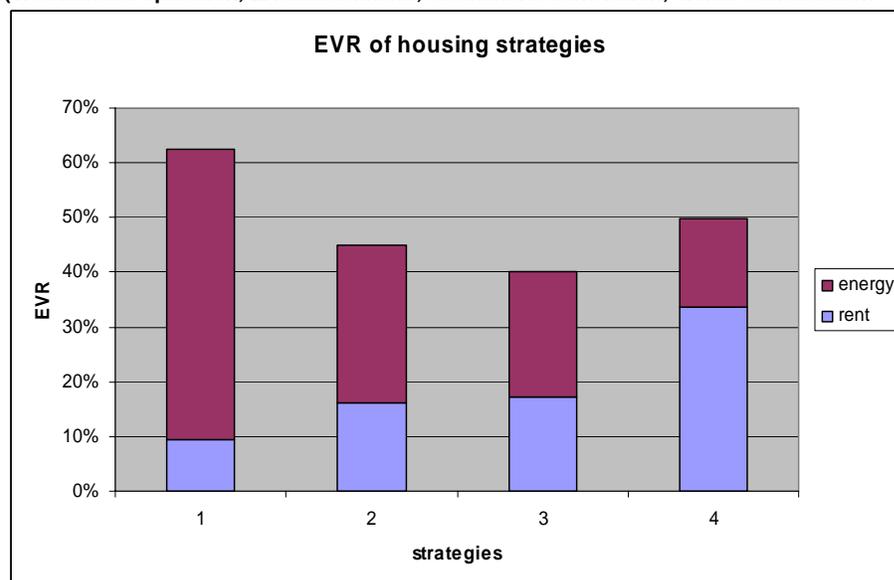
Apart from rent, housing expenses also consist of energy costs. The levels of energy costs following the varying interventions are assessed with help of the energy demand estimating tool (DGMR, 2004).

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 graph B, 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.

Graph 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 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.

Graph B: The Eco-costs / Value Ratio of housing expenses at several strategies (1. continued operation, 2. refurbishment, 3. extensive renovation, 4. new construction)



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