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SUSTAINABILITY, FINANCIAL AND QUALITY EVALUATION OF DWELLING TYPES "SUFIQUAD"

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FINAL REPORT PHASE 1
SUMMARY

SUSTAINABILITY, FINANCIAL AND QUALITY EVALUATION OF DWELLING TYPES

"SUFIQUAD"

SD/TA/12A

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January 2009

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Karen Allacker, Frank De Troyer, Katrien Putzeys, An Janssens, Carolin Spierinckx, An Vercalsteren ***Sustainability, Financial And Quality Evaluation of Dwelling Types "SUFIQUAD"***. Final Report Phase 1 Summary. Brussels : Belgian Science Policy 2009 – 8 p. (Research Programme Science for a Sustainable Development)

In Belgium, as in other countries, the construction sector is responsible for an important part of the total environmental impact, of which housing represents a significant fraction. Current approaches aiming at a sustainable development of the (building and) housing sector, are focusing on the different aspects separately (material suppliers, energy use of end users, etc.), abstracting the complex interrelations. This allows for a detailed analysis but misses a global objective by losing the overall picture. Strategies are needed to evolve to a sustainable development of the construction and housing sector in Belgium.

The **aim of the research** is to strive for more sustainable dwellings. The research departs from the need for an integrated approach aiming at a typology-specific analysis of the sustainability of the dwellings in all aspects. Within the research the complex interaction is analysed between the choice for a certain housing typology, lifestyle, spatial characteristics, technical solutions for building elements on the one hand and the qualities, the financial and the environmental consequences on the other hand.

In order to stimulate action by the stakeholders in the building sector and associated policy fields, the project aims at producing 'identifiable' results instead of general statements. Therefore the research is focusing on different dwelling typologies. Typology specific recommendations are expected to lead to recognizable actions since these are more directly linked to one's personal situation.

The aim of this research can briefly be summarized as the development and application of a methodology to evaluate both the initial and future costs (financial and environmental) and benefits (qualities) of different representative housing types of Belgium. Investigating a number of technical, spatial and user behaviour parameters will lead to identifiable recommendations for the stakeholders and form a basis for policy making.

To come up to this aim, different **methodological steps** were defined. First a proposal for 'integrated' approach was made to enable the evaluation of the environmental impact, financial cost and qualities of the dwellings. Secondly, this approach was translated into a work instrument and tested on several extreme dwelling types in a third step. Both the methodology and the work instrument were revised and updated based on the analysis of each extreme dwelling type. Moreover the revision will be continued in the second phase of the project. Finally, representative dwelling types for the Belgian housing stock were selected, which will be analysed with the revised tool in the second phase of the project. A first proposal with policy recommendations was formulated based on the findings of the extreme types. These will be revised and further elaborated at the end of the second phase.

A proposal for an integrated approach was developed based on a literature review and the experience of the three partners. The integrated approach resulted in a combination of different existing techniques: classic financial evaluation techniques (f.e. Life Cycle Costing (LCC), investment evaluation, cost-in-use simulations), traditional environmental evaluation methods (Life Cycle Assessment (LCA), environmental external costs) and a quality evaluation based on a Multi-Criteria Analysis (MCA).

At the start of the project a literature study was executed on the experience within the European context (and other interesting countries) about both the methodological aspects and policy measures concerning sustainable building. The most important findings were summarized in the 'Note on European research and standardisation' (126 pages). Two important conclusions from this document were that many instruments exist concerning one of the aspects of our aimed integrated approach, but none of these include all of the aspects. Moreover, most of the available tools are 'black boxes' which made it impossible to analyse these into detail. Concerning the policy measures, we could conclude that European initiatives were being taken, but that the implementation within the different countries differed.

Besides this study on existing methods in the European context, a literature review was executed on the different aspects of the proposed integrated approach. This concerned LCA and LCC at the building level, quality evaluation of buildings and methods to optimize several criteria. Based on this literature review and experience of the partners, methodological decisions were taken and a proposal was formulated for the integrated approach. The 'Note on optimising economic, environmental and quality aspects' (130 pages) summarized this. Very briefly the integrated approach consists of a LCA and LCC of a building expressed per m2 floor area per year using the element method for cost control as starting point for structuring the data of the complex object of the dwelling. As a second angle of analysis, 'one inhabitant, per year' and 'dwelling, per year' are also considered as functional units to investigate the importance of size of dwelling on the results. The quality of the dwellings is expressed in a single score by executing a MCA based on an existing Flemish method which was revised within this research. The revision concerns an update of the score functions and of the weighting factors. The quality evaluation is seen as an essential part of the 'integrated approach' since on the building level no identical functional units are definable. Different typologies represent different qualities, but also within a certain typology different qualities can be obtained depending on the design, size, choice of building materials, etc. Finally the three aspects are optimised through a cost-benefit analysis (CBA) by searching for the Pareto front. By using this optimization technique the total cost is evaluated. The total cost represents the financial cost as well as the environmental cost, for both the investment and the cost-in-use. During this optimization the qualities were also considered. Translating the environmental impacts into monetary terms significantly reduces the number of solutions on the Pareto front and is therefore part of this research.

For the translation of the environmental impacts into monetary terms, a literature study was executed. The damage function approach was selected and monetary values from different literature sources were combined in order to address as many impacts as possible. The method is therefore called "hybrid method". The findings were summarized in the 'Note on monetary valuation of environmental impacts' (48 pages).

For the LCA aspect, an appropriate database had to be selected. Therefore an analysis of existing LCA databases was done. This is summarized in the 'Note on LCA data in view of the project' (36 pages). The analysis of existing databases, showed that there was on the one hand no database available specific for the Belgian context, on the other hand there was no appropriate database found containing data about building elements. All appropriate databases only contain data about materials. Therefore it was proposed to use a European database of building materials. Ecoinvent was selected as preferred database, however, if data were lacking other databases were used. A database of building elements was created based on the Ecoinvent database.

For the LCC aspect, an identical approach was used and based on a literature study, it was decided to use the ASPEN database for the cost data. This was summarized in the chapter on LCC in the "Note on optimising economic, environmental and quality aspects" and in the "Note on LCC" (15 pages). ASPEN is a database valid for the Belgian context and contains data at the element level and is thus most appropriate for this research. Both data for new buildings and renovations are available. Energy prices and economic variables were taken from official statistics, while data about frequencies of maintenance and replacements were gathered by a literature study.

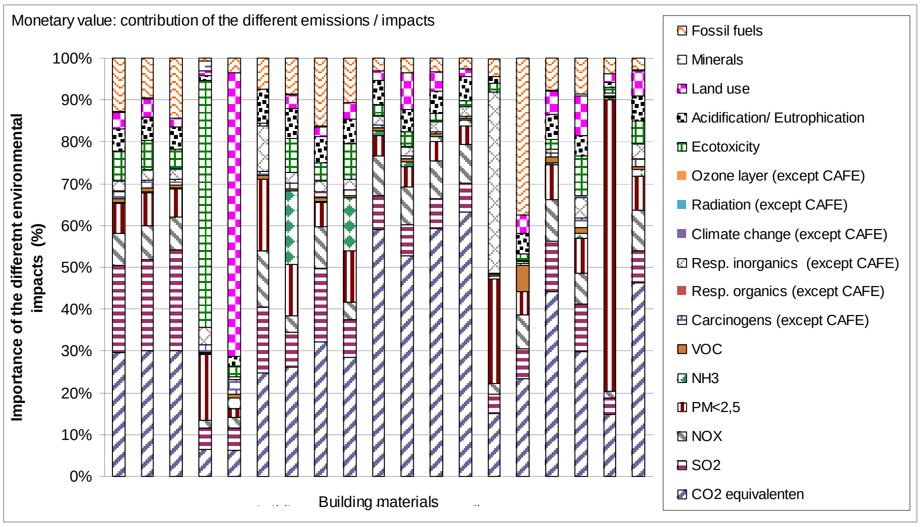
In a second step the methodology was translated in a first version of work instrument (to be used by the partners only). In a first step the general structure of the spreadsheet was established and data were being gathered. Since specific data for the Belgian context were lacking for transportation distances and means, an limited inquiry was set up consulting the Belgian constructors asking about their specific data concerning transport of products to the building site, transport of construction and demolition waste, and EOL treatment of construction and demolition waste.

Moreover, also the quality evaluation was translated into a work instrument. This translation was elaborated in detail in the "Note on quality evaluation" (35 pages). It was opted to translate the evaluation method in two separate files, an "input" and "analysis" file in order to enable revision of the methodology later and analyse all input files with the revised method.

Finally a method was selected to calculate the heating demand of the different dwellings during the use phase. Different available tools were investigated and compared, namely EPB (Energy Performance for Buildings), EAP (Energy Advice Procedure) and EPC (Energy performance certificate). Based on this comparison, the EPB tool seemed the most appropriate for application within this research.

In a third step, four extreme dwelling types were selected: a freestanding and terraced house, an apartment (all newly built) and a renovated terraced house. After the selection of the dwelling types, different (extreme) alternatives for the constituting building elements were defined and described in detail. Moreover, technical installations for the different dwellings were selected. This was summarized in the "Note on selection of extreme types" (75 pages).

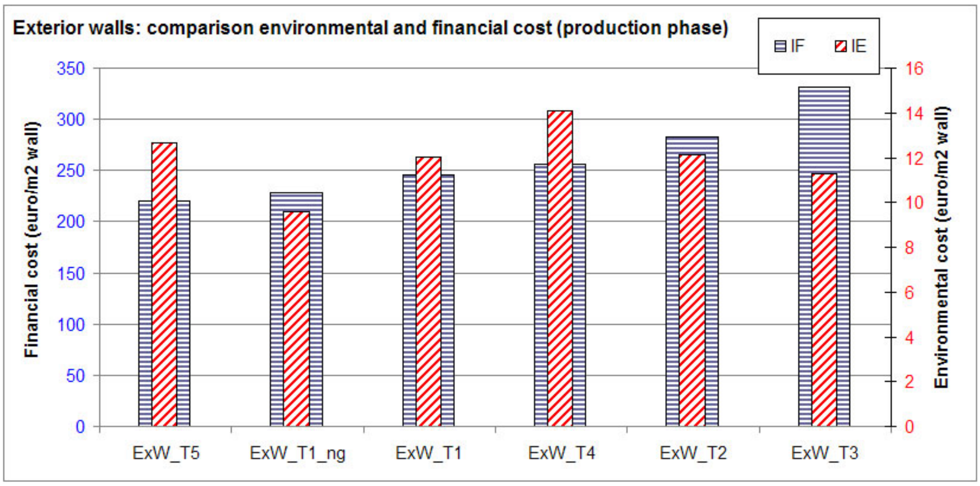
In a next step, the selected extreme dwelling types were analyzed. Both the methodology and work instrument were further developed gradually when implementing it to the extreme dwelling types. The analysis started with an analysis at material level, evolving to element level to end up with the analysis at the building level. This was elaborated in detail in the "Final note on extreme cases" (139 pages). The main conclusion from the analysis at material level (production of materials) was that it is important to include as many environmental impacts as possible within the analysis.



This is illustrated in the figure above, showing the relative contribution of the different emissions and environmental impacts to the total environmental cost of each material (cradle to gate data taken from Ecoinvent, per kg of material). The graph could suggest that double counting occurs. However, this is not the case. The monetary values for the considered emissions (VOC, NH_3, PM<2,5, NOX, SO_2 and CO_2eq.) are not included in the other considered environmental impacts.

From the figure we can conclude that for some of the building materials, the external costs for the CO_2-equivalents are responsible for approximately 60% of the total external costs from all environmental impacts, but for other materials land use (65%) or dust-emissions (70%) are most responsible.

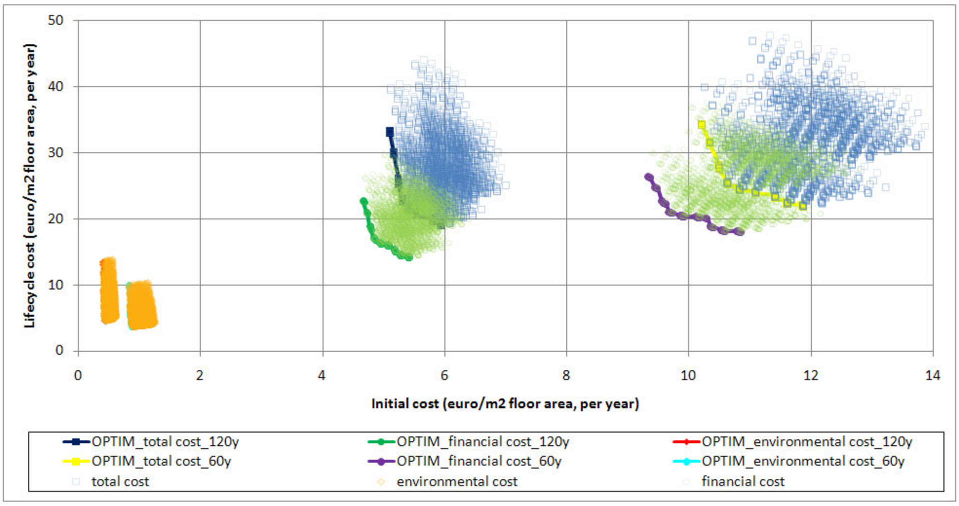
The analysis at the element level (production and construction) revealed two important aspects. Firstly, decisions based on financial cost considerations can differ from decisions based on environmental cost. This is illustrated in the figure below. The figure shows the financial cost (blue, horizontal hatch) and environmental cost (red, inclined hatch) per m2 wall for different alternative solutions of external walls. The figure shows for example that the preference goes to the first alternative (ExW_T5) compared to the second (ExW_T1_ng) based on financial cost, while the opposite is true for the environmental cost.



Secondly, a detailed analysis of the contribution of the constituting materials of the analysed elements revealed that it is impossible to eliminate part of the materials beforehand in order to reduce the computation time. For example, for an exterior wall, the cavity ties were contributing more to the environmental impact of the wall than the gypsum plaster. This was surprising since the limited kilograms of cavity ties in comparison to gypsum plaster. Moreover, for an intermediate floor, the ceramic tiles contributed for approximately 70% of the total environmental impact, while this was rather expected for the structure of the floor. We also have to realise that these figures are for production only, the EOL phase are not included yet.

Finally an analysis at the building level was executed for each of the extreme dwelling types. Moreover, a preliminary comparison of the four dwellings was done.

For each of the alternatives of the extreme dwellings, the initial cost and the life cycle cost per square meter floor area, per year was calculated and graphically represented. This was done for the environmental cost, financial cost and sum of both. Secondly, the solutions on the Pareto front were searched and analysed in detail. This is illustrated in the graph below for the newly built terraced house.



The most important conclusions are the following:

- The costs during the use phase are in nearly all cases the most important ones. These can be divided into heating costs and costs for cleaning, maintenance and replacements. The results show that (for the selected scenario) heating costs are more important than cleaning, maintenance and replacement costs for some of the dwelling alternatives, whereas for other alternatives, both costs are almost equally important,
- the EOL phase was only partially included in the analysis since the financial cost data for the demolition and EOL treatment were lacking,
- the analysis of the extreme dwelling types revealed that the building elements which contribute most to the total initial cost are different for the different dwelling types,
- the financial cost is contributing more to the total cost than the environmental cost,
- while for the environmental cost, heating is the most important aspect, for the financial cost, cleaning, maintenance and replacements are most important,
- an optimisation of the dwelling stock based on environmental cost would focus on heating first, while an optimisation based on financial cost would mainly focus on cleaning, maintenance and replacement costs, followed by initial costs,
- internalising the environmental costs in the financial costs would mainly influence the energy prices (with 40%) while it would have a smaller impact on material costs (10%),
- a difference in quality was revealed between the different dwelling types. The freestanding house was obtaining the highest average score, followed by the newly built terraced house, the renovated terraced house and the apartment,
- decisions based on financial costs were not identical to the ones based on environmental costs, whereas decisions based on total costs were more or less in line with decisions based on financial costs,
- the solutions on the Pareto front based on cost optimisation were not identical to the solutions on the Pareto front considering the quality of the dwelling,
- transportation of inhabitants of the dwelling during use phase is causing an important environmental and financial cost, amounting to more than 60% of the total life cycle cost. This indicates that beside the characteristics of the dwelling the location of the dwelling is also very important.

Moreover, an overview of the **current policy and initiatives** concerning **sustainable building in the Belgian context was made** on request of BELSPO and the guiding committee. This was summarized in the "Note on Belgian policy" (40 pages). Finally, a first **proposal for policy recommendations** was elaborated based on the SuFiQuaD approach and first results of the application. This was summarized in the "Interim note for policy preparation" (14 pages).

In preparation for the second phase, **representative dwelling types** for the Belgian context were **selected** based on a literature study. This is elaborated in the "Note on selection of representative dwelling types" (41 pages). Moreover, representative building elements were selected and described in the "Note on selection of representative element types" (32 pages). The same accounts for the selection of the technical installations, summarized in the "Note on technical solutions" (21 pages). The representative dwelling types will be analysed during the **second phase** of the project. Based on these results a document with policy recommendations will be elaborated.