Sustainable Building Maintenance

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Abstract

As a part of the Sustainable Building concept, the attention for sustainable building maintenance is increasing. Unfortunately, knowledge development has focussed on new building. The available information to support and steer decisions on the existing stock from the viewpoint of durability, is therefore relatively poor.

The maintenance and refurbishment market, however, equals the new building sector in production size. This legitimates specific attention to environmental issues in this particular section of the market.

Sustainable building management is now a firm part of the Dutch governmental environmental policy. It is one of the focal points in the recent "Plans of Actions" designed by the Ministry of Housing to steer developments towards a more sustainable built environment. In recent years, several projects have been carried out, investigating the durability of maintenance activities and aiming to improve building practice.

This paper utilizes the results of these projects. It describes options for the parties involved in the building process to consider sustainability in respect to maintenance. In the design stage, the future maintenance expenditures are determined to a large extent. A well-considered selection of materials and careful detailing, helps to control the expected maintenance activities.

Principals, building owners and managers play an important role in establishing a sustainable maintenance policy, containing environmental requirements for maintenance activities. Developments towards performance contracts will affect the maintenance industry. Those contracts would then contain an agreement on the qualitative and quantitative maintenance levels to be preserved over a period of time.

Sustainability may be one of the requirements requested by the customer or even by changed building regulations. This will further increase the building team's responsibilities regarding sustainable aspects.

Keywords: Building maintenance, building process, durability, life spans, management and organisation of maintenance, sustainability

1. Introduction: the history of sustainable building

The attention for sustainable building started to grow about 20 years ago, mainly due to the increasing need to save energy. The oil crisis in the beginning of the seventies was an important turning point. From that moment onwards, governments started to be actively involved in energy saving. In a later stage, the increasing environmental awareness lead to durable building projects and legislation.

In the Dutch building regulations environmental aspects, such as the prescription of sound insulation, thermal insulation, and ventilation, and the prohibition of applying hazardous materials are covered. At this moment, more performance requirements in relation to sustainable building are added.

In the Netherlands, National Environmental Policy Plans have been made since **1989.** Low energy building is widely applied. The number of refurbished dwellings with energy saving measures has increased rapidly. Research gradually supplies index numbers to compare alternative building designs on durability aspects. All parties involved in the building process are convinced of the importance of sustainable building and are prepared to support further developments. They are, for instance, entering into "Durable Building" agreements. In the housing sector, measures are incorporated in large-scale projects. In the Environmental Council for the Construction Industry parties involved in building are in continuous debate on possibilities to improve the sustainability of the building sector.

Up to a few years ago, the programmes mainly aimed at new building, and less at the existing stock or civil structures. Now, we see that urban aspects acquire more attention and building management becomes a separate object of research. Sustainable maintenance and refurbishment is gaining more awareness, specifically in the social housing sector. Many housing associations are drawing up environmental policy plans, of which maintenance and refurbishment form part. Installing double glazing, replacement of local heating systems by improved or high performance systems are normal activities for most corporations. Some of them even use listings of preferred materials.

To be able to pay attention to the sustainability of the existing stock, parties involved will need adequate information on the durability aspects of their decisions. This paper gives an overview of those aspects.

2. The maintenance and refurbishment market

In Europe the maintenance and refurbishment sector account for a building production equal to that in the new construction market. For the Netherlands, the current size of the market is over 29 billion guilders. An overview is given in figure **1** [1]. The maintenance sector increases with 1,5% per year due to an ageing building stock. The size and growth of the existing market justifies more attention for maintenance and refurbishment issues.

The building industry is responsible for a considerable share in the total waste production. For 1993, the Dutch Institute for Public Health and Environmental Protection calculated the amount of building and demolition waste to be 12,8 Mton [2]. The maintenance and refurbishment sector creates an important part of this waste, due

to the small scale and labour intensiveness of the activities. Reuse and recycling possibilities are therefore important issues. This gives another reason to pay more attention to refurbishment and maintenance from an environmental point of view.

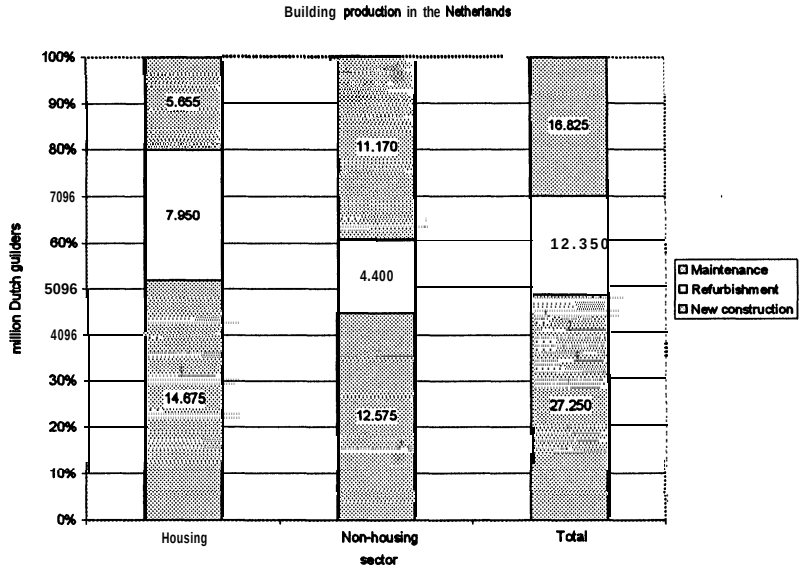

Figure 1 Buildingproduction in the Netherlands

3. Sustainable maintenance

The Dutch Environmental Policy Plans define sustainable development as "a development which fulfils the needs of the current generation without endangering the possibilities of future generations to fulfil their needs as well". Sustainable building, in line with this definition, is: building in a way that supports a sustainable development. Two types of measures can be applied to obtain a sustainable development. The first type contains measures aimed at reducing harmful effects. The second and most preferred one relates to measures for treatment at source. Those include:

- an integrated life cycle approach;
- the reduction of energy consumption;
- the improvement of the quality of products and services.

Maintenance can be described as: all "activities aiming to upkeep the performance supplied". Maintenance fits the definition of each of the sustainable measures. By extending a product's life span, maintenance reduces the demand for base materials for the production process of new components or buildings (integrated life cycle approach). Reducing the demand for a product also implies a reduction of the energy needed for production (reduction of energy consumption). And, finally, upkeeping a product's performance fits the theme "quality improvement" [3].

At the same time, however, maintenance activities themselves require material and energy. The reduction of the environmental impact, accomplished by prolonging the life span of components, should therefore be weighed against the impact imposed by the maintenance activities themselves.

3.1 Maintenance and integrated life cycle approach

The urgency to prolong a building component's life span from an environmental point of view, depends on its environmental impact during its life cycle. Data on this environmental impact are presented in so called Life Cycle Analyses. LCAs structure the environmental effects of products or activities in the different stages of their life cycle.

At this moment, no universal LCA-method exists, although several parties (for instance ISO) are working to establish such method. This obstructs the comparison of product alternatives. Therefore, a comparison presently is often based on qualitative judgements and rules of thumb. The lack of a reliable life span forecast in LCAs, vital to make a realistic estimate of the environmental impact, is another problem to be solved.

Maintenance activities have to be reviewed for their environmental implications as well, and LCAs should be developed for those activities. The impacts of a specific activity can then be compared to the impact of alternative actions. The main aspects in the evaluation of maintenance from this point of view are:

- the maintenance cycle: the more often an activity should be repeated, the larger the impact;
- the impact of the activity: for instance the amount of energy needed, pollutants released (such as dust or hazardous emissions), hazardousness of its waste (such as asbestos), and the annoyance to the building users (such as noise), indicate this impact;
- the environmental impact of the products used for maintenance (for instance solvents released in painting or glueing).

In the Netherlands, the Netherlands Steering Committee for Experiments in Housing (SEV), the Netherlands Agency for Energy and Environment (NOVEM) and the Dutch Foundation for Building Research (SBR) have published manuals with sustainable building activities for housing. These manuals also cover the refurbishment and maintenance sector [4,5,6]. Similar manuals are currently being developed for the utility sector.

3.2 Sustainable maintenance and the reduction of energy consumption

Most measures relating to energy conservation do not fit the definition of maintenance, as they imply improving the energy performance, rather than upkeeping the "old" performance. Insulation measures are, however, often applied when a component is to be replaced for technical reasons anyhow. As such, they can be incorporated in the planned maintenance policy. For instance: if a roof cover is in a bad condition, the extra costs of replacing the cover by an insulated one are relatively low, compared to adding insulation during the component's life span.

If a component is replaced before the end of its life span to install a more energy efficient component, the extra waste, material and energy use caused by this untimely replacement should be considered and weighed against the benefits of this replacement in terms of energy saving.

To reduce the energy consumption of actions, both the efficiency and effectiveness of maintenance measures should be considered. Reducing the amount of an activity is important too. The amount of building "skin" (external surface) appears to be

indicative. The maintenance need of a design can be estimated beforehand, to anticipate and facilitate design revisions.

3.3 Durable maintenance and improving quality

Maintenance is only useful if a building component will remain in use for sometime afterwards. This may sound logical, but in many cases, the maintenance planning is not adapted to the owner's future plans with his building stock. The horizon of a maintenance planning can be as far as 25 years ahead. If the owner considers a major refurbishment, selling or even demolition of the building, maintenance should be adapted accordingly. Re-use and waste reduction measures should be considered.

The "repairability" of a building component is another aspect of improving quality. In relation to sustainability, there will be a strong preference for repairing components rather than replacing them. This repairability has proven to be a problem in realising a long life span for a number of so-called "low-maintenance" products. Those products indeed have a low maintenance need during the life span, but if a failure occurs by accident, this defect often can not, or only at a very high price, be repaired. A minor defect can thus result in full replacement or demolition and wastage of high quality products. Paying timely attention to repair possibilities would have prolonged the component's life span. Accessibility of components for maintenance activities should be considered in this respect as well.

Improving the quality of maintenance can also affect the choice of the activity itself. The nature of maintenance and refurbishment activities often complicates attunement between parties involved in a project. Examples of inefficient building processes are abundant. Paying more attention to the logistics of maintenance processes would favour sustainability.

4. Relationship between durability and life span

Durability in daily life is used in its meaning of "long lasting". However, from an environmental point of view, durability has many more aspects than this technical life span only; a product can only be considered durable if there is an actual need or, in market terminology: demand, for that product [7]. Nowadays, instead of the word "durable" the word "sustainable" is used.

The life span of a product should be attuned to the demand. If the demand ceases to exist, the product should either be completely disintegrated and cause as little waste as possible, or it should be re-usable (demountable and re-usable) or fit to be recycled.

For maintenance activities this implies that no maintenance activity should prolong the life span of the component longer than the required period, and that no materials should be applied lasting longer than the component's life span, unless recycling is possible. The concept of flexible, open building plays an important role in solving this problem [8].

Life span information is essential in determining the sustainability of any solution. Products with minor environmental effects, but a very short life span, can have the same environmental impact as a product with more effects but a very long life span, due to the necessary continuous replacements of the short-lived component.

At this moment, reliable life span information on buildings and their components is still missing. There is no universal, objective and internationally accepted standard

method to determine the life spans of components yet, although several committees and groups, both within and outside CIB, have been addressing this problem.

5. Sustainable maintenance strategy

In recent years, the Dutch organisations SEV and NOVEM have supported projects and experiments in the area of energy reduction and sustainable refurbishment. In the DUWON-project, a methodology and manual were developed for durable maintenance in housing [5]. The manual requires housing owners to evaluate their maintenance policy from the combined viewpoint of maintenance, environment, market strategy and economics.

In the realising a more sustainable built environment, the client, whether consumer, building owner, investor or building manager has a major responsibility in requiring sustainability in the early stages of any building process, whether new building, maintenance or refurbishment.

Maintenance is a part of real estate management. As such, decisions relating to maintenance should involve more than just technical matters. Changing consumer requirements in relation to the building market as well as financial and legal matters can set preconditions and objectives for maintenance activities. These preconditions and objectives should be considered if evaluating sustainability aspects of maintenance as well. Focussing on maintenance only, may lead to suboptimisation. All phases in the building process should be considered to allow the most sustainable solution to be found.

This most sustainable solution may not always be feasible. Reasons may be the limited availability of a material or high costs or less explicit matters, such as lack of experience, implying higher application risks. Unfortunately, new products, which have not yet been tested thoroughly in practice, are often not guaranteed [9].

6. Organisation of sustainable maintenance

Sustainable maintenance involves the reduction of unnecessary maintenance. Unnecessary maintenance can be prevented by carefully planning activities on the basis of the actual building condition. Careful planning allows activities to be executed at the right moment in time, in combination with other activities, and in line with the objectives the organisation has for its real estate. This allows equipment and actions to be attuned.

In condition based maintenance, activities are based on the defects found in a building inspection. These inspections determine the performance supplied by a building. This performance will be compared to the performance required by the building owner or user. This allows actions to be exactly fitted to the requirements of a specific building. In a European research project titled "Condition Assessment and Maintenance Strategies for Buildings and Building Components", the possibilities for implementing condition based maintenance were investigated for several European countries [10].

Duijvestein and van Hal [11] have introduced a stepwise procedure to reduce the environmental effects of building activities. The procedures review both the input and

the output flow of each activity. Applied to maintenance their procedure leads to considerations as described in table 1.

Input	Output
Prevent unnecessary use Is maintenance really necessary? Can the amount be reduced? Can more efficient measures be taken, in terms of performance, life spans, environmental impact, maintenance cycle? Does maintenance solve the existing problems? How should the maintenance activity be executed to decrease the amount of future maintenance? Does maintenance have adverse consequences for surrounding components, diminishing their life spans or endangering their performance?	**Prevent waste** Is it possible to reuse existing materials? Is it possible to diminish the amount of waste due to material processing? Can the amount of packaging be reduced? Are the newly installed materials and components reusable, maintainable and repairable? Is it possible to apply used products or recycled materials? Is it possible to apply materials with a take-back-guarantee of the manufacturer?
Use infinite resources Are the materials used for maintenance renewable? Does maintenance affect the possibilities for reusing the they components treated? Is it possible to use sustainable energy sources for maintenance activities requiring ensuring possibilities for future use electricity? Is it possible to use human power in stead machine power?	**Reuse waste** Is it possible to disassemble components in such way that are fit for high quality reuse or recycling? Recycle waste wisely, using clean technology and of Can the building waste be subdivided in separate fractions? Is it possible to store the second hand goods for future use? Can activities be executed in such a way that recycling is easy in future?
Use limited resources wisely (clean technology and high return) Is it possible to execute activities in an efficient way in order to use less energy (logistics, attunement of activities)? Is it possible to use equipment, which needs less energy? Is it possible to use less material without losing quality?	

Table 1. Sustainability considerations relating to maintenance input and output

7. Performance contracts

Relatively new are the developments towards performance contracts, for instance discussed in the conference of CIB W60 in December 1996 in Tel Aviv. Next to contracts on the performance of new buildings, parties are now discussing possibilities for maintenance contracts as well.

In maintenance contracts, parties agree upon the performance level to be maintained by a supplier, usually the maintenance contractor. The customer is usually the building owner or manager. Another form, not yet applied but expected in future, is a contract between the building owner and user, expressing the performance level to be maintained by the owner and the user and the obligations and rights of each of them. Next to the technical and functional performance, such contracts could contain requirements on the sustainability of the maintenance activities as well.

8. Conclusions on future actions required

A method for evaluating the sustainability of maintenance plans should now be implemented on a large scale in the building industry and translated to fit all building types. Incorporating sustainability in the building regulations will be an important step

forward and it will force building owners and' users, specifically in the private and commercial sector, to reconsider their policy.

Further research is required into the life spans of building components. Parties involved in the building process should agree on an acceptable methodology for the determination of life spans. A plan should be made to expand this methodology to obtain real life data and a forecasting model to estimate life spans of new materials and products.

Parties should also agree on a standardised LCA-method. This method should also be used to determine the environmental effects of maintenance activities. Both the effects of the activities themselves, as well as the consequences of activities for the life spans and possibilities for reuse of the components maintained, should be taken into account. By classifying activities on their environmental impact a well considered selection becomes possible. CIB could take a leading role in establishing an international task group in this area.

References

1. EIB, *The expectations for the building production and employment in 1997*, (Dutch title: De verwachtingen voor de bouwproductie en de werkgelegenheid in 1997), Economisch Instituut voor de Bouwnijverheid, Amsterdam, 1997
2. *RIVM, Data I993 - Building and Demolition Waste,* (Dutch title: Meetgegevens 1993–Bouw- en Sloopafval), 1993
3. Hermans, M.H., *Durable Maintenance,* (Dutch title: Duurzaam Onderhoud), in: Vademecum voor Architecten, part D, pp. 1 – 27, October 1996
4. Stuurgroep Experimenten Volkshuisvesting, *Manual for Sustainable Housing,* (Dutch title: Handleiding duurzame woningbouw), SEV, November, 1993
5. SEV and Novem, *Manual for Sustainable Maintenance Management in Housing,* (Dutch title: DUWON Duurzaam Woningbeheer), SEV en NOVEM, June 1997
6. Jansen, P.F.C., *National Package for Housing,* (Dutch title: Nationaal Pakket Woningbouw), Stichting Bouwresearch, Rotterdam, 1996, ISBN 90-5367-l 75-7
7. Hermans, Marleen, *Deterioration Characteristics of Building Components, A data collecting model to support performance management,* PhD-thesis, Eindhoven University of Technology, Eindhoven, 1995
8. Hermans, M.H., Quah, L.K., Damen, A.A.J., *The Market Potential of Industrialised Flexible and Demountable building for the Dutch building Industry,* (Dutch title: De marktpotentie van industrieel, flexibel en demontabel bouwen), for the Dutch Ministry of Economic Affairs, Rotterdam, 1997
9. Hermans, M., *Possibilities for extending the guaranteed life span of building products,* (Dutch title: Mogelij kheden voor een langere gegarandeerde levensduur van bouwprodukten), for the Governmental Building Agency and the Ministry of Economic Affairs, Rotterdam, 1996
10. Damen Consultants (Project co-ordinator), *Condition Assessment and Maintenance Strategies for Buildings and Building Components,* Brite Euram project 4213 for the Commission of European Communities, Rotterdam, 1996
11. Duijvestein, K., Hal, A. van, *Ecological Building,* (Dutch title: Ecologisch Bouwen), in: WEKA, Bouwen en Milieu, 2ell 1 t/m 24, WEKA uitgeverij, Amsterdam, July 1993, ISBN 90-70829-3 1-2