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PQE: A METHOD FOR TENDER EVALUATION

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Summary

In a misguided ambition to benefit the environment some severe restrictions are often put on the design process which can lead to a limited competition among the contractors that will result in higher prices and will obstruct the use of innovative solutions. Moreover the environmental objectives can be vague and lack the association to the quality of the object.

The PQE method is intended to overcome these obstructions by providing an instrument for dynamic decision making in the tender evaluation process of buildings in which the production, quality and environment are balanced in a way that reflects the goals and prerequisites of the client.

This can be done by applying cost functions that describe the performance of the building with respect to its durability, materials and environmental impact, health and comfort, moisture protection, sound insulation, energy usage and the depletion of resources. The dynamic cost parameters are then given a monetary value in accordance to the goals and values of the client, on the basis of which the client can choose the most economically feasible alternative that meets the functional requirements of the program as well as the demands of the national legislator and the local building authorities.

The method is based on functional requirements, as opposed to prescribed solutions, since the aim has been to develop a tool that does not favour any particular actors or methods and thereby supports the use of inventive technical solutions.

Paramount to the method is that the building be approached on a system level and from a life-cycle perspective.

The choice of function categories aims to capture the factors with the greatest potential to contribute to sustainable development as well the most common areas of problems in the Swedish building industry.

1. Introduction

The concept of life cycle economy has served as a model for the methodology that is now widely applied when the environmental impact of buildings is assessed. The scope and purpose of such environmental evaluation methods is, however, very varying. Subsequently, many of the methods are more appropriate when comparing the relative performance of different components while other are less able to connect the environmental qualities to the economical decision making that has to be done in the design phase and the procurement process.

1.1 Life Cycle Economy

During the years from 1965 to 1975 Sweden saw a big explosion in the production of multi family housing. More than one million apartments were built in a government program that unfortunately put all the effort on reducing the cost of production, while the future costs of maintenance and operation were more or less neglected. Nowadays the importance of evaluating the life cycle costs of buildings is, however, widely acknowledged even if there is much work to be done in spreading the use of life cycle economics.

The focus of life cycle analysis can be either the life cycle cost or life cycle profit. In short the life cycle cost is the sum of all costs during the whole life cycle and can be written as

$$C_0 = \sum_{t=0}^{T} \left(O_t + M_t\right) \cdot \frac{1}{\left(1+p\right)^t} + I_0 \qquad (1)$$

C_0	Life cycle cost
I_0	Initial cost
O_t	Operation
M_t	Maintenance
p	interest rate (inflation?)
t	time variable
T	cost optimal life time (or chosen period)

Life cycle profit, on the other hand, is the whole income after the deduction of all life cycle costs (Bejrum, 1991). The calculation of life cycle profit is obviously dependant on knowledge of the income which makes the life cycle cost calculations more practical when comparing the cost of different alternatives.

The scope of life cycle calculations can vary, depending on the purpose of the study. It may include whole building in which case a life cycle profit calculation makes it possible to maximize the profit of an investment. Needless to say the benefits of such an analysis are the greatest when applied in the design phase of the building process.

Life cycle methods can also be applied in order to choose between different solutions for parts of a building, such as the type of construction for a roof or a façade, but it can be difficult to associate such choices with the economy of the building as a whole (Bejrum et al, 1996). The results can for instance be used to determine in what manner a certain level of insulation should be reached, e.g. by adding to the thickness of wall insulation or by purchasing a certain sort of window.

Furthermore an economic life cycle analysis can be done on a component level, for example with the purpose of choosing materials for surfaces.

1.1 Environmental Impact

During the past decades, a number of methods have been developed for evaluating the environmental impact of buildings. In general those methods include the effects of the building process as well as the operation and maintenance of the building during the whole of its life span, from “cradle to grave”. One of the most widely used methods is the so called LCA study (live cycle assessment) the original intention of which was to evaluate short-lived consumer goods (Borg, 2001).

The LCA method is quite rigidly defined by SETAC (Society for Environmental Toxicology and Chemistry), the Nordic guidelines for LCA and within the ISO 14000 series (Trinius, 1999). It can be applied on all levels of the building process and constitutes a scientific tool for decision making during the design phase as well as in the operation of existing buildings.

By definition a LCA analysis consists of four distinct phases, that is

- Definition of goal and scope
- Inventories, including collection of data, mass flows and environmental load
- Evaluation of environmental impact
- Interpretation

Evaluation of environmental impact consists of four steps. The first step includes definitions of the environmental impact categories, such as global warming or acidification and is followed up by associating the categories with the presumptive mass flow and environmental loads. The third step includes ranking and weighing of the calculated impact in order to make it possible to do the evaluation. As this makes the method somewhat subjective it is of great importance that the model used is clear and transparent as well as in line with the objectives of the study. The fourth and final step includes conclusions and recommendations.

Today there are many tools available for executing LCA analysis of buildings. Most of them are based on a bottom-up approach in which the combined effects of individual building components and materials are added to give the total environmental impact of the building.

Eco-effect is a method that has been developed at the Royal Institute of Technology in Stockholm. The method takes into account the energy and materials used as well as life cycle costs and indoor air. Each of those is independently analysed and represented with bar charts that show the emissions and their relative impact for each category together with the amount of waste and the depletion of natural resources.

EPS is a method based on the guidelines of SETAC and is based on putting a monetary value on negative environmental effects. The main concept of the method is ”the willingness to pay” to maintain five criteria, namely; human health, biological diversity, fertility, resources and esthetical values. This willingness to pay is measured by the current costs of society of avoiding damage or preventing negative effects. This means that the amount of damage has to be quantified but the evaluation process becomes automatic since the price is predetermined (Hertwich et al, 1997).

BEES is a program that has been developed at the National Institute of Standards and Technology in the United States and can be used for relative comparison of the economic and environmental performance of different alternatives within the same group of products. In BEES there are 12 categories of harmful environmental effects and the environmental impact is therefore evaluated through the problems that must be avoided, such as global warming, acidification and eutrophication. From the weight factor designated to each category an overall score is then given to the product (the lower the better) and through arbitrary weighing of the economic and environmental performance the overall performance is calculated. The calculation model is based on a functional unit of 1 square ft. and a service life of 50 years. The method is based on the circumstances in the USA and does only take very limited consideration to how the different alternatives may affect each other and is therefore less appropriate for the analysis of whole buildings.

Eco-Quantum is a similar method but has been developed in accordance to the needs of the construction industry. The program gives points on the basis of the use of resources, emissions, energy and the amount of waste. Each building component is then given a score based on its performance in comparison with an alternative which will give an indication of where the greatest room for improvement is to be found.

Some efforts have also been made to incorporate the methods for life cycle costs and environmental analysis in calculation models for procurement of cost effective and environmentally friendly buildings. One such model has been suggested by Sterner (2002). The Procurement model is based on interviews, polls and case studies and merges the environmental load from the energy use in the operation phase with the life cycle costs. Sterner founds this approach on own studies as well as earlier research that shows that 90% of the life cycle costs of multifamily buildings are covered with the sum of the initial costs and the energy costs of operation. The rest of the costs are covered by other operational costs together with maintenance and the proportions of those show variations between the different studies. The environmental impact is divided into categories; as is the case for many other models, but the categories coincide by design with the environmental quality objectives of the Swedish parliament. In each category the amount of emitted substance is denoted by the equivalent amount of a reference substance and added to get the total impact for that category. The results for each category are then normalised in accordance to the maximum limit of emission per capita and summarised in order to obtain the “weighted environmental impact index”, WI. The environmental impact index, EI_x can then be derived from the amount of energy used and the source of that energy as well as the efficiency of the heating system that are taken into account by the use of some additional weighing factors. In addition, a specific goal factor, φ is used to reflect the ratio of energy use to the goal set by the client.

The total combined tender price (TCT) is then given by

$$TCT = p + LCC_E + \varphi \cdot EI_X \cdot a \tag{2}$$

where p is the tender price [SEK/m^2], LCC_E is the life cycle cost of energy use, including operation and maintenance and a is an arbitrary factor set by the client that gives a monetary value to the environmental impact index.

2. The PQE method

The PQE method provides a new instrument for dynamic decision making during the procurement of buildings. The method makes it possible to simultaneously consider the price, quality and environmental impact in accordance with the prerequisites and objectives of the client. The client can therefore send unambiguous signals to the entrepreneurs and suppliers about his or her objectives.

Furthermore the entrepreneurs and suppliers are given an opportunity to choose the most economic manner to reach the dynamic requirements of the function. With an objective to provide a certain function the consequence must be a given function at a lower cost or an improved function at the same cost.

The PQE method favours a holistic approach to the performance of buildings since the method allows for arbitrary allocation of the resources that can for instance be used to save energy or to protect the environment. This will enable a supplier of a product with relatively high emissions of CO_2 during the building process to compensate with less reduced energy consumption or better construction solutions with regards to thermal bridges or air tightness.

2.1 Functional requirements

Central to the implementation of the PQE method is the use of functional criteria as a means of describing the performance of a building. According to Erlandsson (2002) a specification of a building can either consist of requirements that prescribe certain technical solutions and materials, or, functional requirements that describe the requested performance. While the requirement of specific technical solutions will put severe constraints on the final product the use of functional requirements enables the specifications to be fulfilled with a multitude of solutions that meet the functional demand. By default the use of functional requirements will not favour any particular supplier or contractor and will therefore promote technical development in the building industry.

The same holds for the environmental requirements that are ideally put forward as functions of the impact made on the environment. This means that resulting environmental impact is derived from the context into which the particular solution is put, that is performance of the building as a whole at the actual conditions of operation.

The PQE method uses fixed minimal requirements that have to be met if a solution is to be accepted together with dynamic cost functions that show how the tender sum is affected by deviations in the functional performance. By making those cost functions dynamic and interactive an opportunity is given to study the whole building on a system level.

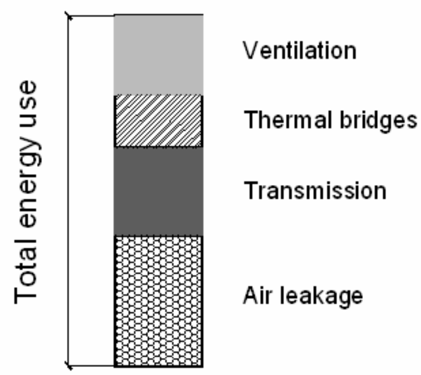

Figure 1 An example that illustrates how the different parameters; ventilation, thermal bridges, transmission and air leakage contribute to the total energy consumption use for space heating. With dynamic requirements the amplitude of those parameters can be changed at will, provided that the sum is below the lower limit, i.e. if the functional requirement of the total energy use is met (Justesen, 2001).

The Swedish legislation concerning the building industry is to be found in a number of different acts as well as local directives. Since 1997 the city of Stockholm has a program for environmental building with an update from 2004. The purpose of the program is to make Stockholm a sustainable city. The program acknowledges the central role of the client in the planning phase since it is the client that makes most crucial decisions regarding the design, construction methods, technical solutions and choice of materials. This on the other hand will constrain the environmental adaptation and use of resources during the operation of the building.

In addition there are special demands made by each client that are not restricted but may be put into the same matrix of functional demands. To summarise we have arrived at the following list of performance specifications.

Durability

Materials and environmental impact

Health and comfort

Moisture protection

Sound insulation

Energy

Resources

Needless to say, the functional requirements must be verifiable. The use of the PQE method does therefore require that the performance, as per calculation in the design phase, is clearly and precisely accounted for. The functional parameters that have been chosen are based on the requirements of the city of Stockholm that are more rigorous than the national Swedish building code.

2.2 Cost functions

Every dynamic requirement consists of a cost function, or an algorithm that affects the final tender price.

Based on a predetermined property and the derivation of the actual value, $E_{actual,}$ from a base value, E_{base} the tender price is adjusted according to a known arbitrary function, for instance if this function is constant the change in price, ΔP, will become

$$\Delta P = \text{Constant}\,(E_{base} - E_{actual}) \quad (3)$$

The dynamic requirements will affect the environmental impact during the building process as well as during operation and will have great influence on the architectural quality and durability. It is important to observe that by requiring the suppliers to account for the implicit dynamic parameters the client will promote a better solution at a given price or a more economic solution for a given quality.

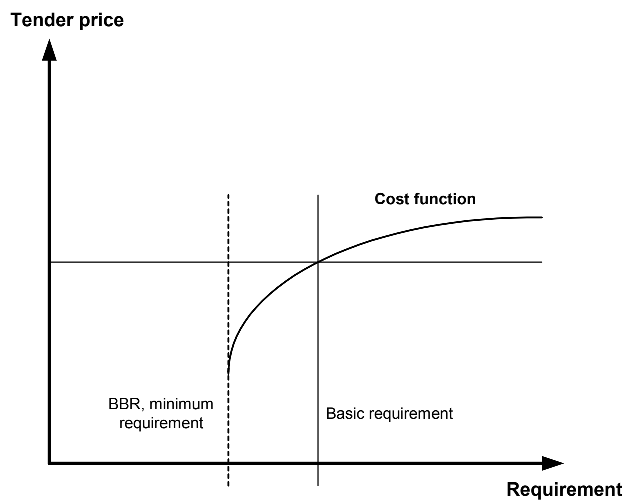

Figure 2 An example that shows the form of a cost function, where the basic requirement represents the goals of the client and BBR is the minimal requirement for building permit.

The table below gives an illustration of what the cost function matrix may look like. The chosen parameters incorporate the most relevant environmental and life cycle factors but do also coincide with the qualities that have to be openly accounted for by the latest legislations and directives in Stockholm and in Sweden.

Table 1 A matrix of cost functions

Function	Cost function parameters
Durability	Lifetime, live-cycle costs of operation and maintenance
Environmental Impact and choice of materials	Emissions, weighted environmental impact
Health and comfort	Number of days above or below certain operative temperature
Moisture protection	(Only minimal criteria)
Sound insulation	Performance relative to class B
Energy	Lifetime, live-cycle costs of operation and maintenance, emissions, weighted environmental impact, energy use kWh.
Resources	Cost of waste disposal during operation and dismounting. Emissions, weighted environmental impact of waste at dismounting.

It is then the role of the client to determine the monetary value that is to be designated to the dynamic parameters.

3. Conclusion

A holistic approach to the design and procurement of buildings has been central to the development of the PQE method. This can be acquired through the use of dynamic cost functions that describe the performance of the building in relation to the demands made be the client and required by law. The cost functions are those of durability, choice of materials and environmental impact, health and comfort, moisture protection, sound insulation and the use of resources and energy. The dynamic cost parameters are then assigned a monetary value that can be used for a procurement process that favours the must economic solution that fulfils the functional requirements. The purpose of using functional demands has been to push towards optimisation of technical functions the qualities of which are measured by the performance of the building as a whole and from a life cycle perspective.

The choice of categories is based on the most problematic areas in the Swedish building industry and the factors that can contribute the most to quality and sustainable development. At the same time it is possible to use the currently required information systems that have been developed in order to calculate and present the technical properties as requested by the national legislator and the local authorities.

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