Quality assurance of indoor environment and energy use

Å. Wahlström, PhD
SP Swedish National Testing and Research Institute
asa.wahlstrom@sp.se ***www.sp.se***

A. Ekstrand-Tobin, PhD
SP Swedish National Testing and Research Institute
annika.etobin@sp.se ***www.sp.se***

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SUMMARY:
To achieve the intended results of building, managing and using a property requires knowledge, continuity and communication, which can be assured by a dynamic and flexible quality assurance (QA) system.). Such a system focusing on high quality indoor environment has been developed and successfully applied during the last ten years. However, although the clients are very satisfied with the QA and its results, they need proven arguments of improved indoor climate and economic benefits in order to be able to justify the increased initial costs. Furthermore, the new European Energy Performance of Buildings Directive will increase the pressure for energy improvement. A one-sided concentration on either good indoor environment or energy efficiency might cause mutual negative effects, and it is important to take actions to avoid this.

Specialist researchers, building proprietors, builders and building managers are, therefore, together developing the existing QA system in an ongoing project. The initial phase of the project is concerned with evaluation of experience of the existing QA system applied to production and maintenance of buildings with a high quality indoor environment. The results will be implemented and form a basis for political decisions on greater use of QA in the building process. The second part of the project aims at extending the QA system by including optimisation of energy use. The possible negative impact of various energy efficiency measures on the indoor air environment is accurately taken into consideration, together with future demands and criteria formulated in the Energy Performance of Buildings Directive (EPBD, 2002).

1. Introduction

From the initial order, through design, construction and up to and including operation, the building process provides opportunities for errors, misunderstandings and compromises that can result in building solutions with a poor indoor environment and/or inefficient use of energy. Why available knowledge is not used, or why quality is neglected, is often due to the client failing first to provide, and then to require, sufficiently specified requirements for design, construction and/or maintenance. This may be because the client is unable to quantify the benefits of improved indoor environment or reduced energy use resulting from better design, construction and/or maintenance. Such improvements involve a higher investment, and it is important for the client to understand that this will lead to reduced costs during the operation phase and therefore be profitable in the long run.

To achieve the intended results of building, managing and using a property requires knowledge, continuity and communication, which can be assured by a dynamic and flexible quality assurance (QA) system. The main target group of the end results are those who will buy or rent a property. It means a lot to know that the building to be occupied has been built and is operated to ensure a healthy indoor environment with minimum use of energy.

A quality assurance system concentrating on achieving a high quality indoor environment was developed during the 1990s and has been successfully applied to schools, offices and dwellings (Samuelson, 2000).

Several buildings have been quality-certified by the scheme over the last five years. The clients are very satisfied with the QA system and its results of an improved indoor environment, with fewer complaints from the building users (Emami and Forseaus , 2004). However, there is a need for a long-term evaluation from previously certified buildings that shows not only the indoor environmental benefits but also the economic benefits. This is necessary in order to be able to advocate and justify the QA costs in future building projects.

In addition, the new European Energy Performance in Buildings Directive (EPBD, 2002/91/EC) will require energy simulations and declarations of the building's energy performance, which in their turn will bring new demands for energy improvements. However, a reduction of energy use is appropriate only if it does not have detrimental effects on the indoor environment. In order to avoid a one-sided focus on either good indoor environment or energy efficiency, that might cause mutually adverse effects, there is a need for extending the QA system to consider energy use as well.

Specialist researchers, building proprietors, builders and building managers are, therefore, together developing the QA system in an ongoing project. The first objective of the study is to analyse the results from the existing QA system for indoor environment in use. The results will be implemented and form a basis for political decisions towards increased use of QA in the building process. The second objective is to include energy efficiency assurance. This paper will describe the existing QA system with the first results from its performance analysis and the basis for the extension of the QA with energy use assurance. Consequences on indoor environment of energy efficiency measures are also discussed.

2. A Quality Assurance System for the Indoor Environment

The QA system for the indoor environment includes the entire process, from planning and design, through the construction stage to final use and operation. Constructing buildings with a good indoor environment requires cooperation between all parties, from scientists and public authorities to designers, contractors, managers and users. All need to listen to each other and to learn from each other, if what we know about the indoor environment process is actually to result in a good indoor environment. A good indoor environment is created as the result of realisation of creativity, planning and layout design, choice of materials, technical designs and systems for heating, ventilation, electricity and water supply.

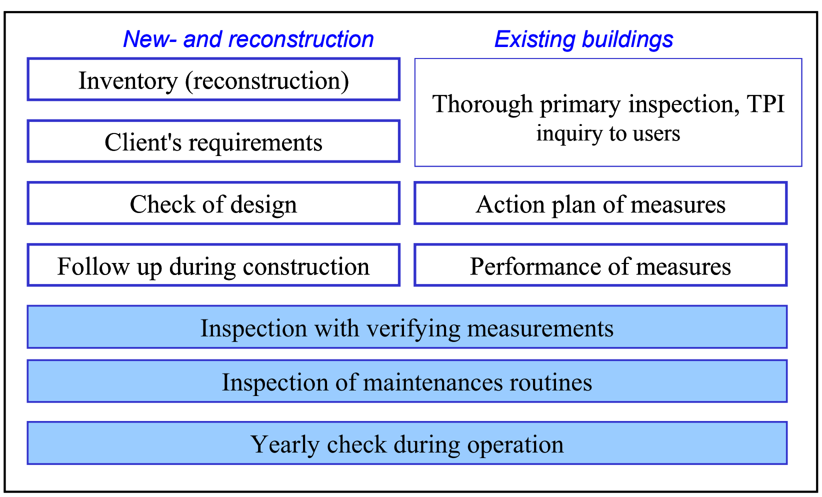

FIG. 1: Illustration of procedures for quality assurance of indoor environment.

This QA system makes sure that the requirements set out in legislation, standards or common codes of practice are fulfilled as intended during the design, construction and operation stages. A third party supervises, evaluates and checks that the requirements are fulfilled. Physical measurements show that the performance requirements have been met. Occupants' perceptions of the indoor environment are evaluated with the help of questionnaires. The QA system includes both new building and renovation work, as well as improvements of existing buildings. The whole certification procedure is based on ISO 9000 procedures, and is described in specific rules for labelling of the indoor environment (SPCR, 2004), illustrated in Fig. 1.

2.1 The design and building phase

During the planning and building phase, the building must be designed to withstand relevant moisture loadings. This means that structures must be designed so that they remain dry, that penetrations and connections are correctly detailed and constructed, and that materials and the site are protected from moisture during construction.

Surface coverings such as flooring materials, carpets and ceiling tiles, as well as formless materials such as adhesives, filler, mastics and paint, must be selected after due consideration of their performance, their contents and their claimed low emission.

A good noise environment must be ensured by the provision of adequate acoustic insulation, low-noise building services systems (ventilation systems etc.), correct room acoustic attenuation and design and the selection of furniture that does not contribute to unnecessary noise generation or reflection. Good lighting conditions must be chosen in order to assist good working performance and concentration. Good thermal comfort must be ensured, right down to the design outdoor temperature.

Clear and easily understood operating and care instructions for the premises are a prerequisite for continued good air quality. The various documents need to be matched to the needs of the target personnel concerned; for example, to the building operator's staff, to cleaners and/or to occupants and users. There are instructions for cleaning, with chemicals to be used having been selected to suit the surfaces to be cleaned, the job to be done and the need for good indoor air quality. The instructions for the heating and ventilating systems provide details of such aspects as the maximum number of persons with which the systems can deal, work being carried out in the building and so on.

FIG. 2: An unprotected and wet building site with clear risk of future mould problems in the wooden structure, especially the sills. Photo: I Samuelson

2.2 The operation phase

In order to ensure the maintenance of a good indoor environment, there must be proper procedures for operation, maintenance and cleaning. All complaints about the indoor environment from occupants, visitors etc. are documented. The details must show how the complaint has been dealt with, e.g. whether checks have been made or what has been done about the problem. The purpose of this is that staff or others should know that there is a system for dealing with complaints, and that there should be early warning of what might be incipient problems.

2.3 Performance analysis

A performance analysis has been carried out in cooperation with building proprietors of previously certified building projects with QA of the indoor environment (Emami & Forseaus, 2004). Experience from the indoor environment in different schools was analysed with the help of questionnaires. The analysis involved personnel and pupils from two schools with QA systems and four schools without QA systems. Although the results show advantages for the certified schools, they also show that it is possible to produce a satisfactory indoor environment without QA. It should be noted that this investigation did not include any measurements, but only the occupants' subjective impressions.

An additional investigation of certified buildings (blocks of flats) in comparison with uncertified buildings is in progress. In this case, the evaluation will be extended with information and practical experience from building managers and maintenance personnel, as well as from occupants.

3. Extension of QA system to include energy use

One of the objectives of this project is to extend the quality assurance system for the indoor environment to include energy efficiency assurance. In addition to the project group, the work involves a reference group of experts in the fields of building services systems, control strategies, ventilation and heating. So far, the first draft of QA-rules has been specified with the main objectives and requirements.

3.1 Objective

The primary objective with energy use quality assurance is to work towards continuing improvements. The aim is to encourage clients, builders, architects, administrators and occupants to perform measures that otherwise would not have been considered. The QA system should not only achieve, but also demonstrate, improved energy efficiency of the building. This requires an action plan for measures as well as quantified and measurable goals.

Energy efficiency performance is demonstrated by expressing the goals in the form of annual energy use (kWh/year). However, this alone is not enough to express the total energy objective, since energy use can also be improved by changing to a more environmentally benign energy source. The energy performance building directive (EPBD, 2002) suggests that indicators for greenhouse gases may also be declared. Energy efficiency should therefore include not only the amount of energy user per year (kWh/year), but also the associated emissions in terms of CO_2-equivalents/year, which describes the impact of global warming caused by the building’s energy use.

The extent to which energy efficiency can be utilised in a building project depends on many factors, such as outdoor climate, building use, location, building design, availability of energy sources etc. This makes it a complex problem, especially for existing building projects for which many conditions are already set or decided, and it is impossible to set an all-encompassing target. The QA system therefore works in a similar way to ISO 14 000, and implies that each building project is unique. Working in conjunction with the QA team, the building project team will set the yearly target for energy use and CO_2 emissions. This means that the targets will be set after considering the building’s current conditions and potentials, rather than according to a specific predefined goal.

3.2 Requirements

The Energy Performance of Buildings Directive (2002/91/EC) came into force on January 4, 2003, and requires an energy performance certification system for buildings to be implemented by January 4, 2006. Work is in progress in Sweden on drafting the necessary legislation and drawing up the rules for Swedish certification schemes. The QA system aims to follow the requirements in the Swedish implementation of the directive, and may need to be amended when compulsory requirements have been decided.

The Swedish Building Regulations are also under development, and new rules will be adopted within the near future (BBR, 2005). All requirements in the Building Regulations must be followed. Requirements for indoor environment should be fulfilled.

Sweden has a statutory requirement for regular and compulsory ventilation inspection of buildings. It is important that this inspection should also provide information for the QA system.

3.3 Flexibility and scope

The QA system should be flexible, setting a limited number of objectives to be reached within a specified time, and not stipulating how the objectives should be reached. This implies a QA system that can certify indoor climate or energy use, either separately or together. The QA mark should clearly indicate if it is indoor climate, energy use, or both, that are assured. Certification work begins with a thorough primary inspection (TPI), which is a substantial part of the certification. This part can be carried out jointly for the two systems, which will make the certification process practical and economically effective. Other inspections can also be coordinated.

In order to ensure continued development and updating of certification scheme rules, as well as to keep certification personnel updated, requires a broad market scope for the QA system. Therefore, new construction, retrofitting and existing buildings are included in the QA system.

3.4 Target determination and control

The QA system considers the fact that each building project is unique, and therefore the building project team in cooperation with the QA team will stipulate the yearly target of energy use and CO_2 emissions. The target decision will thus observe the building's current condition and its related limitations. For new construction, or major retrofitting, the primary limitations are related to building use and climate, while minor retrofitting and existing buildings also have limitations due to design.

The QA team should offer guidelines and recommendations for target setting. Minimum targets for new construction or major retrofitting will be set in the coming Swedish implementation of the Directive, while targets for minor retrofitting and existing buildings could be based on statistics of existing buildings in the same category. Such statistics will be collected in a public data base (eNyckeln, 2004), although statistics from the Statistics Sweden (SCB, 2004) could also be used.

Calculation of CO_2 emissions from energy use and energy sources can be done by life cycle analyses of different energy sources. A data base of life cycle analyses, and a method for emission calculation, are presented in the public Internet program (EFFem, 2005), described in Wahlström, 2003.

A limited number of comprehensive targets should be set and should be chosen so that it will be possible to measure and demonstrate the targets. The QA should include a measurement requirement specification of how the comprehensive targets should be measured and checked. Several minor targets and specification requirements when changing building parts may be recommended in the QA.

The comprehensive targets should be measurable and be checked regularly. The check should verify only that the targets have been reached without influencing the indoor climate, and should not check which measures have been made. If targets are not reached, the building project team should explain why they have not been reached, and suggest an action plan to reach the target.

3.5 Performance

QA for new construction or major retrofitting of buildings begins during the pre-design phase of the construction (see Fig. 3). The building project team and the QA team will work together to specify the energy use objectives, while considering other requirements such as costs, indoor climate, supply of energy sources, supply of materials etc. Drawings, calculations and simulations will help to predict energy use during the design phase. Experience indicates that the design energy use of the building should be lower than the target, since occupants' habits and other unpredicted factors will increase the energy use from that calculated for the building envelope. Energy use will be followed up during construction, and the building services systems will be set up together to minimise energy use. Energy use will increase when the building is taken into use, due to occupants' influence and electricity use for equipment, appliances and building services systems. During the first year, the building's services systems will again be adjusted together, which can be expected to reduce energy use. After a relevant commissioning time (at least four seasons), the targets of energy use will be reached and the building can be certified. Regular operation starts, and the

QA inspection and maintenance procedures ensure that energy use is kept low. If energy use increases, an action plan with measures must be created. This part of the QA system is very important, since the energy use will soon increase without inspection and maintenance, and this is what regularly happens to buildings without a QA system.

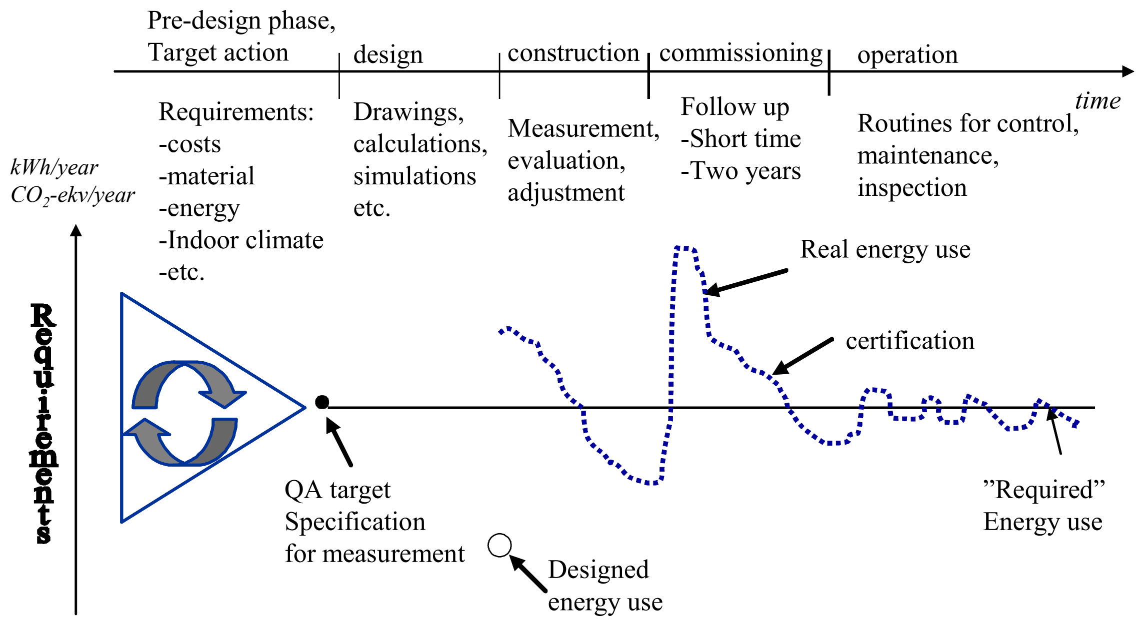

FIG. 3: Illustration of performance of quality assurance of energy use in new and major retrofitting of buildings.

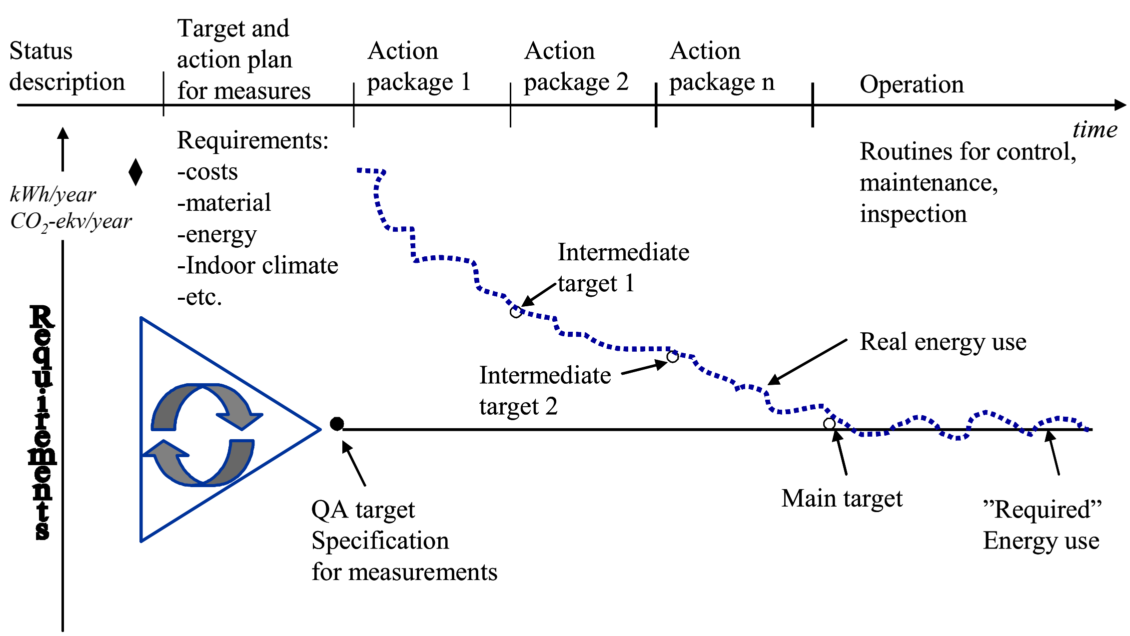

FIG. 4: Illustration of performance of quality assurance of energy use in minor retrofitting and existing buildings.

QA for minor retrofitting and existing buildings begins with a situation description of energy use (see Fig. 4). Working together, the building project team and the QA team stipulate the energy use objectives and an action plan for measures, while considering the present situation and limitations such as costs, indoor climate, supply of energy sources, supply of materials etc. The process can be divided into one or more action packages with intermediate targets. When the main target is reached, the building will be certified. Regular operation then begins, and the QA inspection and maintenance will ensure that energy use is kept low. If energy use increases, a new action plan with measures must be created.

3.6 Labelling

At present, the QA rules have been developed for declaration of energy use and the building's performance is judged only in terms of whether targets are reached or not. It could be beneficial, in an extension of the QA system, to grade the buildings in respect of their performance: e.g. as Class A, B or C. Such a labelling system could be developed in future versions of the QA system.

4. Effects of efficient energy use on the indoor environment

Introducing increased efficiency of energy use in a QA system increases the risk of adverse effects on the quality of the indoor environment. It is therefore of great importance to consider each of these aspects during the procedures of building design, choice of materials, construction and maintenance. Extra attention and design are needed in order to improve efficiency without causing noticeable effect on the indoor environment. Some possible sub-optimisations that should be avoided by proper consideration are shown in Table 1.

Table 1. Some possible sub-optimisations to consider and avoid in the future QA system for high quality indoor environment and efficient energy use

Energy efficiency measures	Consideration	Adverse effect on the indoor environment
Lower indoor air temperature	Risk of thermal discomfort	Increased IAQ complaints
Extra insulation of unheated roof spaces	Need for good airtightness and no possible leakage of moist air into cold roof space	Smell from attic mould
Change of heating system	Need for additional ventilation	Increased level of indoor air pollutants, risk of surface mould and increased IAQ complaints
Reduced ventilation e.g. night time turned off ventilation	Risk of IAQ deterioration	Increased level of indoor air pollutants, risk of surface mould and increased IAQ complaints
Change to energy-efficient windows	Need for additional ventilation	Increased level of indoor air pollutants, risk of surface mould and increased IAQ complaints

5. Discussions and conclusions

The new European Energy Performance in Buildings Directive will bring new demands for energy improvements that might draw attention away from the indoor environment. Energy use and a good indoor environment are strongly related in many respects, and an improvement in one might have an adverse effect on the other. A reduction in energy use should not be at the expense of a poor quality indoor environment. Possible energy efficiency measures must therefore be evaluated in conjunction with their impact on the indoor environment. Future demands for buildings will require an adequate indoor environment with minimum use of energy. The preliminary results from this project show that this can be realised by using a practical and flexible Quality Assurance System, intended to design and maintain a good indoor environment and efficient energy use, with minimum risk of complaints from users/buyers and minimum risk of moisture damage and maintenance neglect.

A QA system for better design, construction and maintenance involves investments in development and inspection of ordinary parties' routines. The preliminary results from this projects show, however, that the QA system will lead to reduced costs during the operation phase, with satisfied occupants and more effective maintenance work.

6. Acknowledgement

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