Life-cycle commissioning of energy efficiency and indoor climate

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ABSTRACT

Numerous studies and everyday experiences prove the fact that even new buildings do not perform as expected. Dissatisfaction with the indoor air quality and thermal comfort is common and the energy performance is not on the targeted level regardless of the new technologies utilized and advanced systems installed. To avoid these kinds of situations quality assurance procedures known as Building Commissioning have been developed in many countries and taken into the use especially in USA. In order to start similar activities in Finland a R&D project was carried out in 2004-2006 as part of the Finnish Building Services Technology Programme (CUBE). In the collaborative project including VTT, Tampere University of Technology and many public and private actors from construction sector general guidebook for commissioning was developed and for the commissioning (Cx) a Finnish term "Toimivuuden Varmistaminen" (ToVa) was launched.

In the guidebook general procedure for ToVa activities is described covering the whole life cycle of the building. ToVa means clear definition, capturing and documentation of end user requirements and their compliance assessment and verification in all the phases starting from design through construction to the operation and use. In the guidebook special focus has been put on the indoor air quality and energy efficiency. Guidebook includes general instructions for the assessment and verification of IAQ and energy efficiency but gives also checklists to be used in different phases of building process. Organizing and response-bilities of ToVa-activities as well as methods to be used in different phases have been discussed in guidebook. In a separate report useful measurements for ToVa have been described and instructions for practical work are given. For the deployment and further development of ToVa-activities internet domain (www.tova.fi) have been set up and www-based tools for some ToVa-activities have been developed. In the paper this Finnish commissioning guide will be discussed and some internet based tools will be demonstrated.

1. INTRODUCTION

Building commissioning is not nowadays in Finland a standard procedure applied during the life-cycle of building. Most often it is used only for new buildings when handing-over the results of construction work to the owner and user. Sometimes it is used as a separate measure in existing buildings as well but in general use of Cx is still more an exception and typically quality control procedures are applied only in the end of construction phase.

However it has been commonly accepted already quite long, that to assure the over all quality of the construction output it is not sufficient to check the quality of final product only. Instead the whole process and life cycle of building should be taken into account (ASHRAE 1996). Therefore Commissioning (Cx) process should be launched already in the very early phase of programming to check that owner's and users' needs and requirements are clearly defined and documented, and that indoor and energy performance requirements are included to owner's program. In addition, it should be audited that design solutions and installation outputs meet given requirements, and verified that the building satisfy given requirements for indoor conditions and energy performance when in use. Cx should also take care that the needs of the operation and maintenance (O&M) phase are considered already in the previous phases and the O&M personnel have knowledge and skills to take care of the systems installed. Finally during occupation Cx should be included as a continuous routine of facility management process over the building life cycle.

In this way Cx activities can contribute to the following goals:

- To provide safety, healthy and comfortable spaces for living and business
- To improve design quality by more effective feedback
- To assure that all building services systems are integrated and compatible with each other
- To improve overall energy efficiency of buildings and building systems
- To decrease operational costs
- To improve operation and maintenance activities and ensure the introductory briefing and training of O&M staff
- To improve documentation during the building life-cycle
- To meet customer needs and expectations and satisfy customer requirements

2. CX PROCESS

In Figure 1 there is the outline chart of the general Cx process developed for Finnish building industry (Pietiläinen et al. 2007). The Finnish procedure was developed based on the American standards (ASHRAE, 2005) and international collaboration carried out under International Energy Agency (Visier et al. 2004). Those international descriptions of Cx processes were the starting points for the development of this Finnish model.

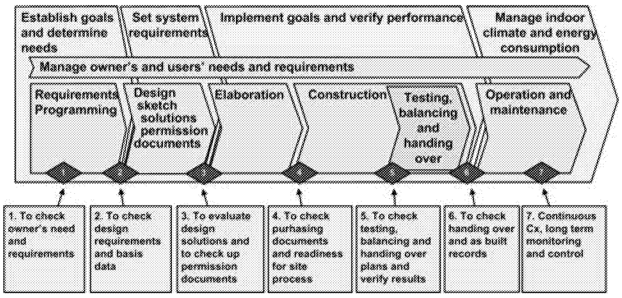

Figure 1. The Cx (ToVa) process.

At the beginning of a construction project, goals are established and the owner's and users' needs are determined. Then, the system requirements are set with the help of design procedures. Thirdly, the goals are implemented and performance is verified in the elaboration and construction phases. Finally, indoor climate and energy consumption is managed by the building services and automation systems of the building. In general checkpoints presented as "diamonds" in Figure 1 link the Cx activities to the building process phases in the following way.

2.1 Requirements and programming review

The objective of this phase (diamond 1) is to ensure that the owner's and users' needs and requirements are defined and documented. During the project planning different options to fulfill the owner's needs are clarified, plans for the project budget are made and the goals for the next phase (diamond 2) are defined.

Key activities are to:

- Check the owner's future strategies and action plans
- Check the owner's and users' needs and requirements
- Check the construction site and detailed town plan
- Check different goals and requirements and identify the possible risks

2.2 Design requirements review

The objective of this phase (diamond 2) is to ensure that the design requirements and basic data are relevant for setting up the system requirements. This information is also used to draw up contracts.

Key activities are to:

- Check design goals and requirements
- Check design contract documents
- Check that maintenance and monitoring requirements are sufficiently included

2.3 Design solutions and permission documents review

The objective of the phase (diamond 3) is to ensure that the design concepts and permission documents are correct. Indoor climate and energy consumption are based on the design concepts, so proper results can be obtained only if the design concepts are relevant.

Key activities are to:

- Check design concepts
- Check building permits
- Take into account the system integration point of view

2.4 Purchase and contract documents and construction site reviews

The objective of the phase (diamond 4) is to ensure that the purchasing documents are relevant and the construction site is ready for implementation. In this connection, it is important to accept all system specific objectives with all the contracting parties. Especially, the integration perspective of different subsystems and procurements must be taken into account.

Key activities are to:

- Select and accept the systems to be implemented
- Calculate the design and construction cost levels for every system
- Agree the functional requirements for all systems

Check that the tender documents meet bidding requirements

2.5 Functional testing and balancing review

The objective of the phase (diamond 5) is to ensure that the testing, balancing and hand-over plans are relevant. The main focus is on final tests and preparation for hand-over.

Key activities are to:

- Make sure that the systems and subsystems are functioning as agreed
- Make sure that the agreed level of indoor climate can be achieved
- Make sure that the assignment and maintenance manuals are relevant

2.6 Hand over review

The objective of the phase (diamond 6) is to ensure the hand over; also the as built records play an important role. At this phase the interoperation of all systems is crucial.

Key activities are to:

- Review all possible defects in the hand-over process and assess the repair work to be done
- Make sure that the building is faultless
- Make sure that all subsystems are tuned and operating as planned

2.7 Long term review of operation and maintenance

The objective of the phase (diamond 7) is to ensure that the indoor climate and energy consumption are managed and monitored for the optimal performance of the building during its whole life cycle. At this phase the continuous commissioning tools play an important role.

Crucial activities are to:

- Monitor the indoor climate, energy consumption and water consumption
- Measurements, audits and functional tests can be used when needed

3. CX MANAGEMENT

Before any Cx activities can be realized, a project specific Cx plan must be prepared and a qualified Cx team gathered. In the following, these issues are shortly discussed.

3.1 Cx plan

It is necessary to prepare a Cx plan according to the project phases. When available, general commissioning planning procedures support the Cx manager's work. However, different building projects have different features like size, complexity, and procurement method or risk profile. Altogether, the Cx manager should prepare a project specific overall plan and detailed phase plans in cooperation with the owner and the design professionals. In Figure 2 there is shown a procedure for preparing a Cx plan. When making the plan several important aspects must be taken into account. In the implementation of the Cx activities a number of checklists and verification documents are also needed and in guide book there are examples of them included.

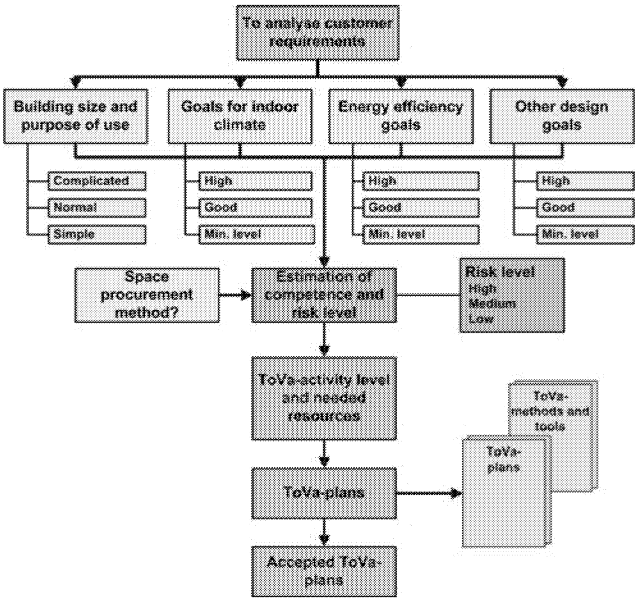

Figure 2. Preparing a Cx plan

3.2 Cx team

Different procurement and delivery methods establish different starting points and terms to organize Cx activities. In the traditional Design-Bid-Build (DBB in Table 1) projects the owner must hire also a Cx manager. In the Design Build contracts the owner has only one contracting party and it is possible to transfer at least some of the Cx responsibilities to the general contractor. It's the question of the owner's strategy and decision, how detailed commissioning process he wants to implement. Table 1 gives examples for selecting the Cx manager in different type of projects.

Table 1. Options to select a Cx team manager

Cx manager ◆ Strong role ● Participation ○	Small DBB project	DBB project	Design Build project	Design Build project	DBOM project
Principal designer (Architect)	●	◆	●	●	●
Independent Cx consult (ToVa)			◆	○	○
Owner's agent	●	○	○	○	○
General contractor's agent	○	○	○	◆	●
HVAC designer	◆	●	●	●	●
Electrical designer	○	○	○	○	○
Construction designer	○	○	○	○	○
Automation designer	●	●	●	●	●
FM service engineer					◆
Supervisor	○	○	○	○	○
HEPAC contractor	○	○	○	○	○

According to Finnish Land use and Building code every building project must have the principal designer. Tasks and responsibilities of the principal designer are partly similar with Cx responsibilities. It is necessary to adjust the role of a Cx person with principal designer tasks. In many cases the principal designer and the Cx manager could be the same person. It's also related to the project size and complexity as well as the professional background of the principal designer.

The most building projects are rather small or medium sized. The Cx team manager may be an external consultant. On the other hand, the Cx manager can be seen as a role and he or she could also be a design professional, a FM service engineer or an owner's supervisor. In certain projects the Cx manager may be a service provider's agent as well. In very large and complex projects, it's a better to engage the whole external commissioning team.

4. CX MEANS PREVENTATIVE APPROACH

Prerequisites for the thermal performance of the building, the energy efficiency and indoor conditions are basically set already in the design phase. Figure 3 shows where during the process there are the biggest possibilities to have an influence on the performance. Paradoxically the users will find the deficiencies and failures when it is very expensive or at least more difficult to improve or repair them.

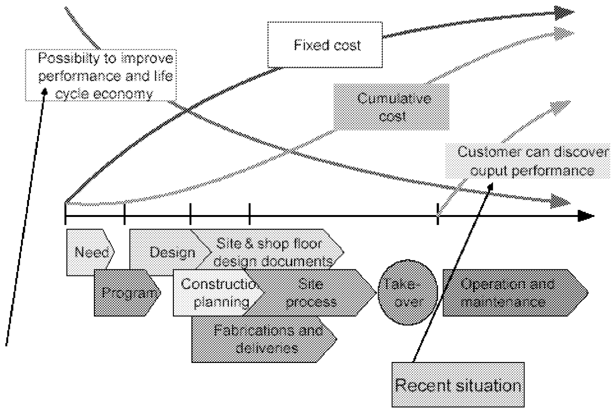

Figure 3. Potential to affect the performance of a building

Therefore it is very important that already in the design phase the designer pay attention to the details, which may cause problems in the installation phase or during the use. In cold climate conditions, especially, the proper functioning of the building envelope is very essential in terms of thermal conditions. Indoor environment contains many factors and thermal conditions depend on

- the performance of exterior walls
- the functioning of ventilation (and cooling) system
- heating system
- building automation system and controls
- internal loads and external loads (weather)
- activity of the user and/or operator

The thermal conditions are a result of integration of the systems. For example the details of exterior walls and, the heating and ventilation system solutions close to the possible risky areas must be revised. In new building, during the last years the following structural details have caused problems at least in the Nordic climate (Kauppinen, 2006):

- large windows with narrow metal frames, often close to outer surface

- two windows in the corner with 90 ° angle, joints of windows in the corner

- large window areas combined with low-temperature floor heating (direct or storage heating, based on electrical heating or hot water circulation)

- complex structures of exterior walls (lot of corners and junctions)

- lead-ins, doors

- thermal bridges, especially the connections of intermediate floors and exterior walls.

The parts of the wall must be tight enough. Air leaks through the structures cause local cooling and draft. The designer should verify the possible impacts of various detail solutions on thermal comfort and thermal performance even though thermal comfort calculations are often time-consuming and require special skills.

5. CX TOOLS

If the plans are properly done, installations are carried out as they should, and the performance has been confirmed also by calculations, the problems which may occur are caused by faults in installation or, in some case, by misuse. The performance of structures and systems must be confirmed with performance tests in the implementation stage but various measurements are needed especially when the building is occupied and in use.

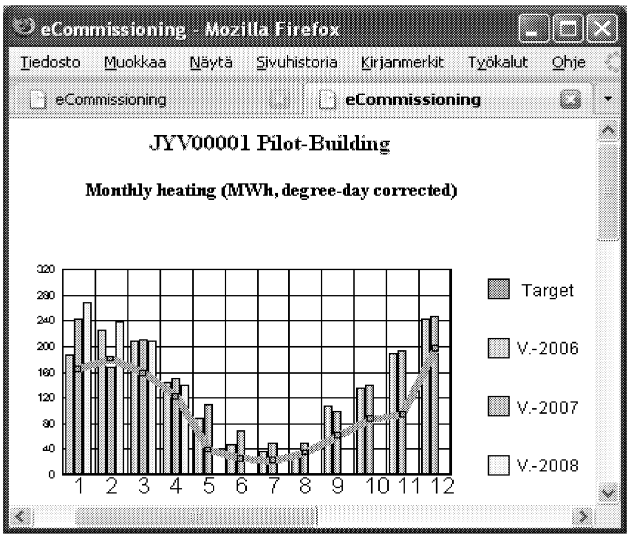

Figure 4. Energy performance monitoring results

Continuous energy monitoring must be organised to be sure that the targets for energy performance will be met in longer term too. In the Figure 4 there is an example of a kind of www-based Cx tool visualising the realised energy consumption of a new school building. The targets set in design phase on the basis of detailed simulations are not met because of failures in heat recovering system and changes in occupation.

For the performance verification various measurements (air tightness, draft, temperatures, pressures, air volumes, lighting levels etc.) must be carried out as well and a special guide complementing the Cx guidebook is under preparation and will be published in 2008.

Figure 5. Example of an electronic O&M handbook

In practice successful Cx relies on reliable and up to date information but it must be utilized efficiently as well. Thus proper information management is crucial and should be started already in the very early phase of the process. Electronic O&M handbooks (www-based applications) are becoming common and will in the future facilitate the Cx tasks (Fig. 5).

6. CONCLUSIONS

Cx concepts and processes are not yet widely accepted and in use in Finland. The new guidebook will facilitate the adoption of new procedures however. In the building industry some big trends also underline the need of a systematic Cx process. Especially global warming, upward energy prices and increasing requirement for good and healthy indoor air are the drivers in near future.

The commissioning concepts and procedures need to match with the actual project and quality management practices however. In addition, the Cx team should match with the normal project organization. So, the key question is the role of the traditional supervisor and the building services supervisor. It´s not sensible only to add an extra Cx organization to the traditional construction project practices. The whole project management needs to be reformulated somehow.

Good indoor environment and energy efficiency are produced and managed by the same systems of building. Strategic objective of Cx is to integrate the building envelope with the other technical systems, especially building services and simultaneously take into account the changing outdoor circumstances and user needs. Prerequisite for the success is active interchange of information and open collaboration among the actors involved in design and construction process. It is also essential to connect the operation and maintenance personnel in early phase to the process, and in this way assure their capability to take care of the building when handed over. Finally the end users (occupants) must be introduced to the proper use and flexible feedback channel to inform about failures etc. should be available.

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