

THE IEA/ECBCS/ANNEX 40 GLOSSARY ON COMMISSIONING

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Summary International Energy Agency's (IEA) Energy Conservation in Building and Community Systems' (ECBCS) Annex 40¹ has developed a glossary of commissioning terms as one of the first commissioning tools produced within the annex. The glossary consists of four major sections: 1) definition of basic terms, 2) explanation of basic terms, 3) commissioning types, and 4) commissioning process. These sections, which were originally developed to facilitate Annex 40 discussions, are now incorporated into an on-line database system. This on-line tool is publicly available on the Annex 40 website and enables users to search for specific definitions and provides links for more detailed explanations, related terms, and existing reference definitions. Using this database system many documents developed in Annex 40 have been actively linked to the glossary for direct access to the definitions. In addition, during the development and review process for the glossary, users are able to submit suggestions for new terms, translations, and other modifications. The purpose of this paper is to introduce the glossary and database system developed in Annex 40 and to invite users to participate in the public review of the glossary before publication of the final report.

Keywords: Annex 40, glossary, database system, building commissioning

¹ The IEA/ECBCS program established Annex 40, a research working group on Commissioning of Building HVAC Systems for Improved Energy Performance.

INTRODUCTION

Although the concept of commissioning is not new, the process of commissioning is still in development in many countries. Because of this, it is very important to clearly define commissioning terms in order to achieve a common international understanding. Annex 40 originally developed a glossary of commissioning terminology based on several existing guidelines and meeting discussions [1,2,3]. Ideally one would want a common glossary that could be applied to all commissioning projects in all countries, but this is probably unattainable because many customary actions related to commissioning are deeply connected to the social structure of individual countries and to the characteristics of commissioning projects. For this reason Annex 40 developed the glossary as a set of idealized definitions that can be customized or adapted as necessary.

This paper presents an overview of four main parts of the glossary: 1) definition of basic terms, 2) explanation of basic terms, 3) commissioning types, and 4) commissioning process, and introduces the glossary database system developed in Annex 40 as an on-line reference. In addition to serving as a reference to the other Annex 40 documents presented at the ICEBO 2004 conference, these two products are designed to be used as an input for the harmonization of international guidelines, as an aid in developing the commissioning process in individual countries, and as an introductory teaching aid for the overall commissioning process and the role of the various players.

Commissioning types are explained first in order to clarify the scope of the glossary before providing definitions and explanations of the basic commissioning terms. The complete set of definitions and explanations cannot be shown in the limited pages of this paper but will be provided in the final report of Annex 40 to be published in early 2005. Until then, the Annex 40 website provides a draft version of the tool for public comment and invites users to submit ideas for improvements (<http://www.commissioning-hvac.org/>).

COMMISSIONING TYPES

Generally, there are four representative commissioning types: 1) initial commissioning, 2) retro-commissioning, 3) re-commissioning, and 4) on-going commissioning. These commissioning types are differentiated based on factors including whether or not the project, building or system is new and whether or not commissioning has been carried out previously. Because Annex 40 work is focused on initial commissioning, the glossary includes a broad range of related terms. It is less detailed for terms related to the other commissioning types, but can still provide useful information when the other commissioning types are considered. Explanations of the four commissioning types, taken from the glossary, are provided below. The related terms and abbreviations found in this explanation (i.e., CA, Cx and CxP) are defined in Appendix A of this document.

Initial Commissioning (I-Cx): I-Cx is a systematic process applied to production of a new building and/or an installation of new systems that begins with the program step and ends with the post-acceptance step. In cases where new equipment is installed in an existing building (e.g., installing a cooling system in an existing building which previously had only a heating system), it should be referred to as I-Cx. Basically, the range of the commissioning process (CxP) implemented depends on the owner's desires and can be defined in a contract between the owner and a commissioning authority (CA). It is strongly recommended that consistency be maintained in the I-Cx process, but before commissioning becomes business-as-usual in a society, there will be cases where commissioning (Cx) in the pre-design and design phases have not been implemented as mentioned in the definition and explanation of 'Preparation Procedure For Commissioning Starting At Construction Phase'. In such cases, the I-Cx can be called 'Partial Initial Commissioning'.

Retro-Commissioning (Retro-Cx): Retro-Cx is the first time Cx is implemented in an existing building in which a documented CxP was not previously implemented. In many cases, design documents of the existing building have been lost or they don't match the current situation. Therefore, the Retro-Cx process may or may not include verification of the design shown in the I-Cx.

Re-Commissioning (Re-Cx): Re-Cx is a CxP implemented after the I-Cx or the Retro-Cx process when the owner hopes to verify, improve and document the performance of building systems. Reasons to re-commission a building are diverse. It could result from a modification in the user requirements, the discovery of poor system performance, the desire to fix faults found during the I-Cx, etc. Periodic Re-Cx ensures that the original performance persists. Re-Cx is the event that reapplies the original Cx in order to maintain the building systems' performance.

On-Going Commissioning (On-Going Cx): On-Going Cx is a CxP conducted continually for the purpose of maintaining, improving and optimizing the performance of building systems after I-Cx or Retro-Cx. The large difference between On-Going Cx and periodic Re-Cx is that the Re-Cx refers to the original building systems performance, while On-Going Cx lays emphasis on the performance optimization. The On-Going Cx is a successive CxP during the Operation & Maintenance Stage to resolve operational problems, improve comfort, optimize energy use, and recommend retrofits if necessary.

DEFINITION OF BASIC TERMS

Commissioning terms, which have been deemed essential to understand the meaning of 'Commissioning', are defined in short sentences and listed alphabetically in Appendix A. Although not a complete list, the terms are presented as a sample of those deemed essential to understanding commissioning and the Annex 40 work. For terms that require a more detailed explanation, a marker '[more]' at the end of the definition signals that additional information is provided in the explanation of basic terms section.

Some of the key points reflected in the glossary, based on the Annex 40 work, are:

- 1) Commissioning should be applied through the whole life of the building,
- 2) Functional Performance Testing (FPT) and Testing, Adjusting and Balancing (TAB) are clearly distinguished,
- 3) The concept of risk analysis is introduced, and
- 4) New tools such as Standard Models of Commissioning Plans (SMCxP) and checklists are defined.

EXPLANATION OF BASIC TERMS

This section of the glossary provides more detailed explanations for some of the basic terms. This list, located in Appendix B, is provided as a reference to better clarify the definitions.

For example, the basic definition of commissioning taken from Appendix A is:

Commissioning (Cx): Clarifying building system performance requirements set by the owner, auditing different judgments and actions by the commissioning related parties in order to realize the performance, writing necessary and sufficient documentation, and verifying that the system enables proper operation and maintenance through functional performance testing. Commissioning should be applied through the whole life of the building. [more]

whereas the explanation of the basic term taken from Appendix B reads is:

Commissioning (Cx): Cx is performed under the supervision of a qualified CA for the purpose of ensuring that building systems are designed, installed and functionally tested, and are capable of being operated and maintained to meet OPR from viewpoints of environment, energy and facility usage. These viewpoints mean to maintain the indoor environment in healthy and comfortable conditions, to minimize the amount of energy consumed and discharged, to conserve urban/global environment, to keep maintainability of the building systems and to give a long life to the building systems.

Additional explanations like the one listed above are provided for a large subset of the terms to clarify various concepts. These term descriptions were broken up into definitions and explanations because it was important to provide a succinct definition, while maintaining a clear explanation of the concept that is not limited by length. The on-line version of this definition is shown in Figure 2, and is discussed later in this paper.

COMMISSIONING PROCESS

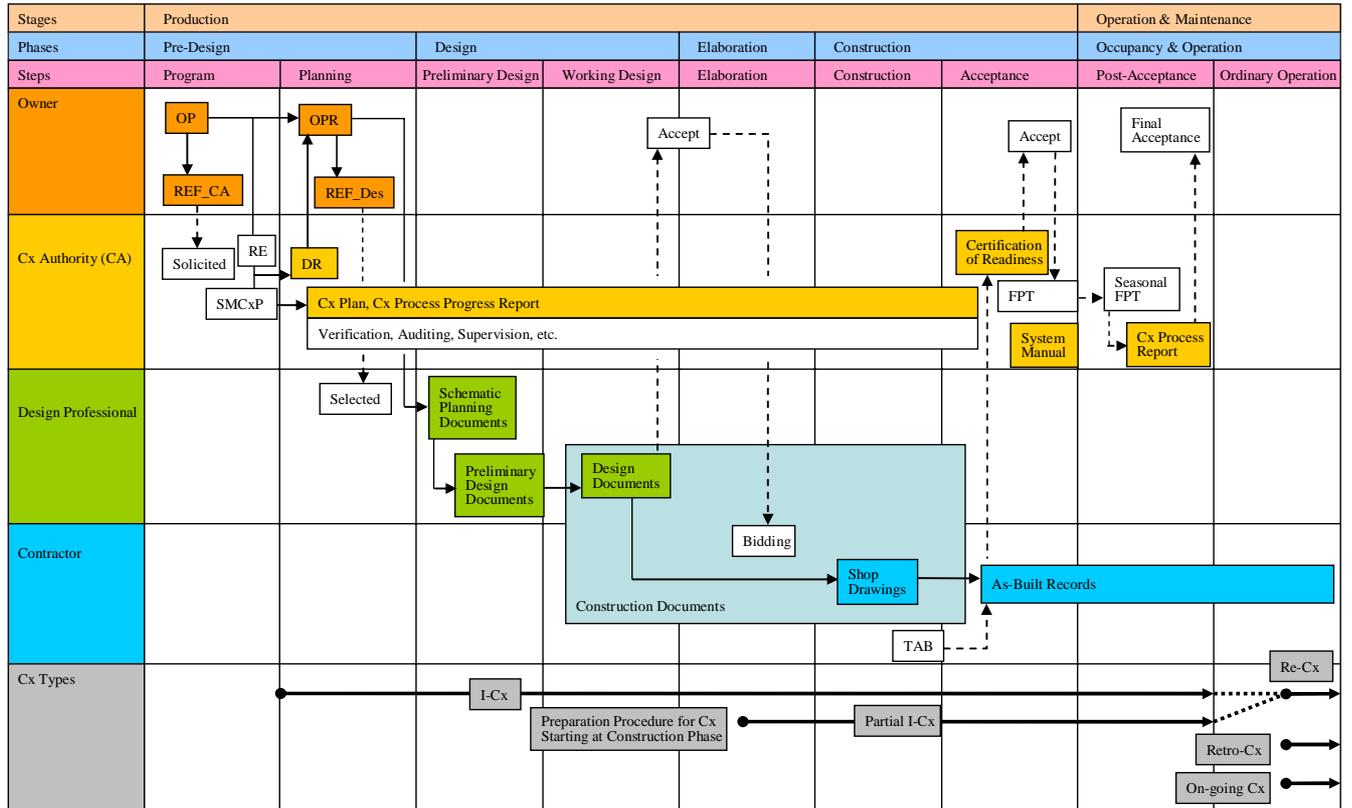
Annex 40 divided the commissioning process into two stages, five phases and nine steps as shown in Figure 1. These stages, phases and steps, described in Appendix C, are necessary to construct the framework for commissioning. Describing the contents of phases and steps facilitates a common understanding for commissioning projects. As mentioned before, the commissioning process is

affected by the social customs of each country and the nature of the commissioning project. Also, it is quite difficult to extract a common commissioning process from different countries because commissioning itself is still in development in most countries. Hence, the Annex 40 descriptions in Appendix C may be mismatched with the social custom of individual countries, but can be useful materials when customizing the commissioning process.

The chart in Figure 1 shows the flow of commissioning documents to illustrate typical steps in a comprehensive commissioning process. The figure is divided into eight color-coded rows. It uses colored blocks to represent documents that must be prepared and white blocks to represent actions that must be completed. Dashed lines show the flow of actions (i.e., selecting the Design Professional based on the REF_Des) and the solid lines show the flow of the document (i.e., the OPR is developed based on the documents of OP and DR). The first three rows provide column headings for each of the commissioning stages, phases and. The fourth row shows the tasks and key documents that relate to the owner. Similarly, rows five through seven show the role of the commissioning authority, design professional and contractor, respectively. The last row shows the commissioning types as a timeline for the activities with initial commissioning process feeding into the other commissioning types.

The next section will describe how all of these sections have been combined to form the glossary tool.

Figure 1: Commissioning process and document flow



GLOSSARY DATABASE SYSTEM

The IEA/ECBCS Annex 40 team has developed an on-line database system that is utilized on the web site. Beyond a list of definitions, it includes information on:

- commissioning types;
- stages of a project;
- documents to be prepared;
- players involved.

The on-line tool enables one to search for specific definitions and provides links for more detailed explanations, related terms, and existing reference definitions. The database enables multi-lingual operation. The base language is English with translations provided in Finnish, French, German, Japanese and Norwegian. Each country participating in the annex has the opportunity to produce a glossary version in their native language or to collaborate with other countries sharing a common language. Discussions were held among native speakers of other languages to prepare the non-English translations of the definitions.

Figure 2 is a screen capture of the web-based tool. The features of the tool are as follows. Below the heading of Commissioning-HVAC Glossary of Terms, is a row of letters, each of which provides a quick link for terms beginning with that letter. The shaded box on the left side is a table of contents/menu that is separated into four sections. The first section provides a link to the glossary home page that gives an overview of the contents as well as a search tab to enable users to locate specific terms. The second section lists the results of the alphabetic lookup. The third section provides links to the definitions of commissioning types and explanations of the commissioning phases and the flow diagram to show the commissioning process overview (Figure 1 of this paper). Finally, the fourth section provides a link to the Administration section that is used by the glossary team to file comments to add a term, modify a term, or provide a translation.

In Figure 2, defining ‘commissioning’ as an example, foreign translations are provided above the basic definition. More information is provided in the explanation and relevant terms are listed below. Finally, the reference definitions published by ASHRAE are also provided for comparison.

The on-line tool enables direct access to the glossary from any of the annex documents. Access to the glossary is also possible from documents produced outside of the Annex by establishing a web link. Clicking on a linked word gives the reader direct access to its definition.



Figure 2: Glossary database system (under development)

During the development and review process for the glossary database system, users are invited to visit the site at <http://www.commissioning-hvac.org>, comment on modifications or translations to the definitions and to create new definitions for consideration. Comments should be sent to the glossary subtask leader at akashi@beel.arch.kyushu-u.ac.jp.

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REFERENCES

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2. ASHRAE Guideline 1-1996 - The HVAC Commissioning Process, American Society of Heating Refrigeration and Air- conditioning Engineers, 1996, Atlanta, USA.
3. Draft-SHASE Commissioning Guideline, Society of Heating Refrigeration and Air-conditioning and Sanitary Engineers, 2003, Tokyo, Japan.

APPENDIX A: DEFINITION OF BASIC TERMS

As-Built Records: Documents that accurately represent actual installed conditions, equipment, and systems, such as drawings, computer graphics, equipment data sheets, operation manuals, and maintenance manuals. They also include the training program and training videotapes.

BEMS-assisted Commissioning: Making use of the control system to perform commissioning procedures. Typically, the control system is used as a means of interfacing to energy systems in buildings through sensor and control signals.

Certificate of Readiness: A document stating that all equipment, systems, and controls have been correctly installed; operated as specified; tested, adjusted and balanced; and are verified as ready for functional performance testing and other acceptance procedures. The commissioning authority issues the certificate of readiness to the contractor after verifying the results.

Checklist: SMCxP customized for practical use. [more]²

Commissioning (Cx): Clarifying building system performance requirements set by the owner, auditing different judgments and actions by the commissioning related parties in order to realize the performance, writing necessary and sufficient documentation, and verifying that the system enables proper operation and maintenance through functional performance testing. Commissioning should be applied through the whole life of the building. [more]

Commissioning Authority (CA): A person, company or organization designated by the owner, responsible for managing the overall commissioning process. [more]

Commissioning Plan: A document written by the commissioning authority that defines the contents of the commissioning process according to the project risk and complexity in order to completely finish each commissioning phase and/or step. The commissioning plan can be defined through customization of standard models of commissioning plans. [more]

Commissioning Process (CxP): A quality-oriented process to accomplish the commissioning aim.

Commissioning Process Progress Report: A progress report submitted during the commissioning process by the commissioning authority to the owner when a phase or step in the commissioning process, a contract deliverable, or the budget year is finished.

Commissioning Process Report: A final report on the results of the commissioning submitted by the commissioning authority to the owner. In the case that commissioning is needed in the post-acceptance step of the initial commissioning process, a provisional commissioning process report is submitted in the acceptance step and the final report is submitted at the end of the post-acceptance step.

Construction Documents: Comprehensive documents for the construction bidding that summarize the design documents, the range and terms of construction, and additional documents needed for bidding. [more]

Design Professional: A legal representative in the design team for the project. In cases where a person and/or group within the design team have primary responsibility for the design, they can be called 'designer'.

² [more] means that the term has a more detailed explanation in the next section. In the web-based tool, this is an active link.

Design Requirements (DR): A document on the basic performance conditions for the design summarized by the commissioning authority and based on the owner's program. [more]

Fault Detection and Diagnostic Tool (FDD Tool): An automated software tool that assists the building operator in maintaining optimal operation of mechanical systems. [more]

Functional Performance Testing (FPT): A set of tests that define the functionality and verify the behavior of a system. These tests are usually defined by the commissioning authority in order to verify that building systems are completed to satisfy the owner's project requirements and demonstrate functional performance. [more]

Owner's Program (OP): A document written by the owner that describes the owner's vision of the project. [more]

Owner's Project Requirements (OPR): A document based on the owner's program and the design requirements. The owner develops it with help from the commissioning authority. [more]

Preparation Procedure for Commissioning Starting at Construction Phase: Specific actions that should be performed before the construction phase when commissioning of pre-design phase and design phase have not been implemented. They are implemented for clarifying the system performance requested in the commissioning. [more]

Request for Proposal (RFP): A document written by the owner to solicit a commissioning authority or to select a design professional for the project. It is called a RFP_CA or RFP_Des. [more]

Risk Evaluation (RE): A specification provided by the owner or the commissioning authority, in which the accepted risk level for the building's HVAC systems is fixed. [more]

Standard Models of Commissioning Plans (SMCxP): Standard models which list typical tasks to be carried out in the commissioning process. [more]

System Manuals: Summary documents describing system operation and maintenance. They are developed by the commissioning authority from the guide for system control and operation provided by the design professional and the system operation and maintenance manual provided by the contractor. They include additional information collected during the commissioning process.

Testing, Adjusting and Balancing (TAB): A testing and adjustment of constructed and installed equipment and systems conducted by a contractor to ensure that the equipment and systems operate to meet the specifications written in the design documents. It includes adjusting water flow in pipes, air flow in ducts, and tuning control parameters.

APPENDIX B: EXPLANATION OF BASIC TERMS

Checklist: A system or building has its own characteristics and may require specific methods, tools and checkpoints for Cx. Those checkpoints can be gathered and arranged as a checklist for a typical system or building. A CA or a project manager will use it when proceeding from one project phase to the next. Since effective tools and practical checkpoints vary from country to country, checklists should be made in each country.

Commissioning (Cx): Cx is performed under the supervision of a qualified CA for the purpose of ensuring that building systems are designed, installed and functionally tested, and are capable of being operated and maintained to meet OPR from viewpoints of environment, energy and facility usage. These viewpoints mean to maintain the indoor environment in healthy and comfortable conditions, to minimize the amount of energy consumed and discharged, to conserve the urban/global environment, to keep maintainability of the building systems and to give a long life to the building systems.

Commissioning Authority (CA): In some countries, the CA must be qualified or certified by an organization authorized by the nation or the state. The CA shall report directly to the owner. For the purpose of maintaining its independence, the CA is generally not the design professional or the contractor in the I-Cx process. The CA organizes a commissioning managing team that consists of persons responsible for working together to carry out the CxP according to the project risk and complexity, plays the role of representative in the commissioning managing team, and finally submits the commissioning process report to the owner.

Commissioning Plan: The design professional develops the design documents including the commissioning specification, the estimation of Cx costs, etc., based on the OPR and the commissioning plan. Therefore, the commissioning plan should include necessary and sufficient information for conducting the Cx at each phase and step in the CxP. The CA needs to develop the commissioning plan in increasing detail according to the Cx progress in order to conduct the Cx correctly. Accordingly, the phase and/or step name and the version number should be included in the commissioning plan to confirm the latest information and the history.

Construction Documents: In a broad sense, the construction documents can include shop drawings added during construction, changes to design documents, admission documents, and the additional information on the construction bidding such as the tasks, responsibility, and costs sharing for completing the CxP.

Design Requirements (DR): The DR detail the building type, the project risk, the conditions of use, and the criteria and acceptable performance of the building energy systems and indoor air quality. The CA develops the DR to harmonize with the budget and the performance of the project based on the OP.

Fault Detection and Diagnostic Tool (FDD Tool): The tool collects control information or other data and analyses them to detect symptoms of abnormal behavior in various HVAC components, such as uncalibrated or failed sensors, actuator or linkage failure, controller instability, non-optimal sequence of operations, etc. The tool also diagnoses their possible causes and provides explanations. It goes beyond the capabilities of conventional BEMS single-point alarms and integrates information from multiple sensors to establish a more comprehensive understanding of the status of operation. One could envision an FDD Tool or a set of tools that would monitor all systems at all times (24 hours a day, 365 days per year).

Functional Performance Testing (FPT): In the case of the systems having seasonal performance, such as HVAC systems, FPT should be continued for at least one year, and subsequently decide the initial performance of the system. For instance, FPT of the HVAC system means to verify that the equipment, subsystems and total system work in harmony (including stability and durability) to

maintain the environment specified in the design documents within the predicted energy consumption. The FPT lays emphasis on the overall operation of the system, and should be differentiated from the TAB on the performance of the equipment itself. The CA may conduct the tests directly, or other members of the commissioning managing team may conduct them. These tests occur during the acceptance step of the construction phase.

Owner's Program (OP): The OP is a document written by the owner that describes the owner's overall vision and philosophy including environmental and energy objectives of the project. The OP outlines the project, the expectations for its use and operation, the baseline project budget, distribution of costs, and expected profitability. The different consultants may help the owner to develop the OP as necessary.

Owner's Project Requirements (OPR): The OPR is a document based on the OP and the DR. The owner develops it with help from the CA. The OPR should be completed during the pre-design phase. If the OP and the DR are fully satisfied, these documents can be filed together as the OPR.

Preparation Procedure for Commissioning Starting at Construction Phase: The preparation procedure for commissioning starting at construction phase is a preparatory procedure that should be performed when the Cx of the pre-design and design phases have not been implemented. The CA audits related documents (e.g. OPR and design documents, or resembling documents if insufficient), clarifies the possibility of Cx, and informs the owner if the design is incomplete. The owner and the design professional meet to resolve the problem. The role of CA at this meeting is to give the owner and the design professional unbiased advice based on professional knowledge to obtain the design characteristics and quality requested.

Request for Proposal (RFP): The RFP_CA is a document written by the owner during the program step of pre-design phase to solicit a CA for the project. The owner requests proposals from prospective CAs for the Cx based on the document. The RFP_Des is a document written by the owner with help from the CA to select a design professional for the project. The owner requests proposals from prospective design professionals for the design based on the document. The request document for a design competition is one kind of RFE_Des used to select a design professional.

Risk Evaluation (RE): The process that identifies the risks related to an HVAC system that does not meet the OPR. It is an overall evaluation of qualitative and quantitative damage if the system does not meet the requirements. It considers the main human risks (e.g. responsibility, knowledge, consciousness, etc.) as well as the main system risks (e.g. risk management, time to discover and react in case of failure, time to get under control, trends, etc.) regarding the probability of its occurrence and the resulting damage (e.g. human health, environmental load, energy savings, cost, image, etc.). Risks can be classified in low, normal, and high categories. The risk is also addressed in the CxP by choosing the appropriate Cx level.

Standard Models of Commissioning Plans (SMCxP): The SMCxP were developed by Annex 40 to help understand the commissioning plan for non-residential buildings and to be applied as one of the commissioning tools. The five SMCxP models are based on the commissioning levels. The commissioning levels are defined based on the combination of the building size, the HVAC complexity, and the risk level. In real projects, the SMCxP would be modified according to the project's characteristics and the social customs in each country and/or state.

APPENDIX C: COMMISSIONING PROCESS

Pre-Design Phase: The pre-design phase is the first phase of the I-Cx process, and is divided into two steps: 1) program step and 2) planning step. In the program step, the owner lays out the project concept as the OP. In the planning step, the owner develops the OPR with the CA. The role of the CA at this phase is to give the owner guidance in drawing up the OPR, and to develop the commissioning plan based on it.

1) Program Step: In the program step, the owner's philosophy on the building environment and performance is established as the OP. The OP includes the outline and profitability of the project and the concept describes the energy conservation and urban/global environmental impact mitigation. The owner makes a RFP_CA, and solicits a CA. In this step, the owner can ask for inside and/or outside professionals on technology, finance, business and construction.

2) Planning Step: In the planning step, the CA makes the DR, and the owner makes the OPR so that a design professional can propose a concrete design. The OPR is developed based on the OP and the DR. The owner releases an RFP for a design professional, and then selects a design professional for the project. Generally, the milestone between the program step and the planning step is when the CA joins the project. The CA develops a commissioning plan, and helps the owner or acts for the owner if necessary to develop the OPR and the RFP_Des and selection criteria of design professional. In this step, the CA considers opinions of the construction manager, facility manager, financial advisor, operation and maintenance staff, occupants, etc., and identifies systems targeted for Cx and documents them. At the same time, the CA helps the owner to estimate costs for design, construction, TAB, consultants, etc. and investigates laws and regulations relating to the Cx. The scope of the work in this step varies widely depending on the project size and owner's requirements for Cx, but the tasks explained above are key points for a successful CxP.

Design Phase: The design phase begins with drafting schematic planning documents and ends with completion of design documents and their handover to the owner. the design professional is selected during the planning step and, depending on the contract, may have the responsibility to make a costs/amounts document based on the design documents, present the design works on site, make a questions/answers document, etc. The design phase is divided into two steps, which are 1) preliminary design step and 2) working design step.

1) Preliminary Design Step: The preliminary design step begins with making the schematic planning documents and ends with completion of the preliminary design documents. The milestone for the end of this step is submission of the preliminary design documents. All contents of the documents must comply with laws and regulations on the building systems. The CA verifies the appropriateness of the schematic planning documents and the preliminary design documents, clarifies the procedure and schedule of Cx, and reviews the commissioning plan again to coordinate with the design intent so that the design professional can clearly write the commissioning specification in the design documents.

2) Working Design Step: During the working design step, the preliminary design documents are further developed into the final design documents. the design professional updates the draft design intent document included in the preliminary design documents, and completes the final design documents based on it. The CA audits the accuracy of the contents of the documents and verifies that the contents are complete. The details of the design work, reviews, and the quality and schedule control are the responsibility of the design professional, but if there are any deficiencies or inconsistencies with the OPR, the CA should point them out directly to the design professional or indirectly through the owner depending on the situation and should instruct their correction based on the owner's decisions.

Elaboration Phase (Elaboration Step): The Elaboration Phase is a transitional phase between the completion of design work and the start of construction. During this phase, the completion of the construction documents, bid submission, bid assessment and selection of the contractor for the construction are performed. The leading person in this phase is of course the owner or the project

manager/construction manager acting for the owner. In cases of private construction, the Design Professional may participate in this work. The role of the CA is to help the commissioning related parties so that the information on the assigned work and the responsibility for the Cx is well shared among the bidding companies. In cases where Cx starts without implementing the pre-design phase and design phase, the preparation procedure for commissioning starting at construction phase that shall be taken for the post facto CxP may be assigned to this phase.

Construction Phase: The construction phase is divided into two steps, 1) construction step and 2) acceptance step. In the construction step, contracting is based on the design documents, and the construction of building systems is started and completed under supervision. Appropriate TAB tasks are also implemented by the contractor. In the acceptance step, FPT is completed under the direction of the CA based on the results of the TAB tasks, and then the building systems are handed over to the owner. The role of the CA is to cope with design changes and to verify the appropriateness of construction supervision and construction control, to inspect TAB performed, to implement FPT, and to plan and implement a schedule of education and training for operation and maintenance personnel.

1) Construction Step: The contractor makes shop drawings based on the design documents, controls schedule and quality of the construction under the instruction of the construction supervisor, installs ducts, pipes, wires and equipment, and implements TAB work. The role of the CA during this step is to correctly convey changes of OPR to the commissioning related parties or propose design changes to the owner through the construction supervisor, and to advise them on their necessity and the possibility/contribution toward achieving requested performance. The CA also audits performance of the construction supervision and control, supervises the TAB work, and confirms the maintainability of building systems with the owner or on behalf of the owner.

2) Acceptance Step: The Acceptance Step is the final step before the building systems are handed over to the owner. The contractor finishes the TAB work on equipment and systems including Building and Energy Management System (BEMS), and completes the as-built records and system operation and maintenance manual. The CA verifies that the TAB work is correctly implemented and that the as-built records are documented fully and correctly. These results are documented by the CA and the document is presented to the contractor as a certificate of readiness. The CA also determines from FPT results if the equipment and systems work and meet the OPR. The design professional and/or the contractor are requested to solve any faults revealed at this step and to properly readjust the systems as quickly as possible. The CA plans the education and training program, and manages it so that the operation and maintenance personnel can completely understand the system manual summarized by the CA. If the CA judges the construction inappropriate and the remaining time for the adjustments before occupancy is insufficient, the CA makes the list of faults to be addressed by the design professional, the contractor and/or the manufacturer, and suggests to the owner that these faults should be corrected during the subsequent Cx of the occupancy & operation phase.

Occupancy & Operation Phase: The occupancy & operation phase is the phase after building systems are completed and handed over to the owner. The occupancy & operation phase is divided into two steps: the 1) post-acceptance step and 2) ordinary operation step. In this phase, the FPT of building systems has already completed, the building systems are operating properly, and the operation and maintenance personnel have been educated and trained. However, in case of systems that need seasonal Cx such as an air-conditioning system, the initial performance of the systems is decided by FPT conducted over at least one year following completion of building systems. The post-acceptance step can be applied in that case. The ordinary operation step continues after the post-acceptance step. The I-Cx process begins with the program step and ends with the post-acceptance step. If the systems commissioned do not have seasonal changes of the performance, the post-acceptance step is skipped.

1) Post-Acceptance Step: The post-acceptance step is applied to building systems in which the performance is seasonally changed and the DR demands confirmation of the annual performance such as an air-conditioning system. This post-acceptance step is the final step of I-Cx process. The role of the CA in this step is to identify the seasonal system performance. For example, in the case

of an air conditioning system, determine the system performance for the peak-cooling season, the peak- heating season, and the intermediate season when cooling and heating modes are both required. Cx during the post-acceptance step includes the seasonal FPT, and the annual performance evaluation and stability of automatic control response, which would be implemented using BEMS in most cases. The faults that were identified in the Acceptance Step to be addressed during this phase should be corrected and readjusted as soon as possible. All of the I-Cx is completed when this step is finished. The CA makes a commissioning process report and submits it to the owner. The term of the post-acceptance step mostly overlaps with the warranty term of the construction, and the seasonal FPT mentioned above is considered to be requested in the range of the construction. There could be cases where the final payment for a project is postponed until one year after occupation, but the milestone between the acceptance and post-acceptance steps is guided by this explanation.

2) Ordinary Operation Step: The ordinary operation step is defined as the step following the post-acceptance step of I-Cx. If the I-Cx itself or the post-acceptance step is not applied, this step would be matched with the occupancy & operation phase. In this step, the evaluation work for the Re-Cx and/or On-Going Cx to identify the unresolved issues, desired changes, weaknesses identified during Cx, desirable improvements identified during Cx, warranty action items, etc., may be addressed. The repeated Re-Cx could correct faults, and the evolution to the On-Going Cx may maintain the building systems in optimal condition through life of the building.