

Develop A Commissioning Process And Template In Building Project For Large-Scaled Construction Company

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Abstract : This study aims to establish building commissioning process for large-scaled construction company, and develop the commissioning template in accordance with each phase. The purpose of this paper is to develop a practical, systematic, professional template for commissioning for a large construction company. In addition, commissioning of buildings is the main subject of performance verification of Heating, Ventilating and Air Conditioning and Refrigeration (HVAC & R) systems that require equipment and control, so we focus on verification of HVAC & R. Large-scaled construction companies in Korea are transforming from general contractors to Engineering, Procurement, and Construction (EPC)s, and it is expected that the role of building commissioning for the objective quality assurance of buildings will be important in the future. In addition, it is necessary to prepare for this, since it is impossible to properly respond in a timely manner to the contractor who must obtain final approval from a professional commissioning company before delivering the building to owner. In order to solve these problems, it is necessary to properly understand the submission documents and work system required by a professional commissioning company and to establish a work performance system to enable commissioning from the General contractor's perspective. As the owner's demand for building commissioning increases day by day, a response to this is necessary, also, the commissioning can respond to the global warming crisis. The research team builds the commissioning template from plan to O&M phase, then, the template contained key documents and general document packages.

Keywords: Commissioning, operating cost, building energy, commissioning document, large-scaled construction company.

1. Introduction

Since the late 2000s, interest in energy saving and eco-friendliness arising from resource depletion along with global warming has been spreading around the United States and Europe, and the demand for eco-friendly performance verification of buildings is expanding. Commissioning, which started from the performance verification of ships and aircraft, is expanding to general buildings, and the building commissioning market is gradually expanding. In the United States, Europe, and Canada, guidelines and laws are established and distributed through various associations, and currently, the introduction and concept of commissioning is spreading. [1-3]

Table 1. Domestic and international guidelines and laws

Type of commissioning	Domestic	International		
		Guideline	Cost/Standard	Association
Initial Cx ¹	None	US ASHRAE ² (‘89~)	UK CIBSE ⁵ (‘60~) Canada CSA ⁶	US BCA ⁷ , CCC ⁸ Canada NRC Japan BSCA ⁹ IEA ECBCS ¹⁰
		UK BSRIA ³ (late 80~) Canada NRC ⁴ (‘93~)		
Re-Cx ¹¹ Retro-Cx ¹²	None	California DOE ¹³ (‘99~) CCC(‘06~)	California NEBB ¹⁴ (‘09~)	

1. Initial Cx : Initial Commissioning
2. ASHRAE : American Society of Heating, Refrigerating and Air-Conditioning Engineers
3. BSRIA : The Building Services Research and Information Association
4. NRC : Natural Resources Canada
5. CIBSE : Chartered Institution of Building Services Engineers
6. CSA : Canadian Standards Association
7. BCA : Building Commissioning Association

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8. CCC : California Commissioning Collaborative
9. BSCA : Building Services Commissioning Associations
10. ECBCS : Energy Conservation in Building and Community Systems
11. Re-Cx : Re- Commissioning
12. Retor-Cx : Retrofit Commissioning
13. DOE : Department of Energy
14. NEBB : National Environmental Balancing Bureau

Large-scaled construction companies in Korea are transforming from general contractors to Engineering, Procurement, and Construction (EPC)s, and it is expected that the role of building commissioning for the objective quality assurance of buildings will be important in the future. [4] In the current situation, the lack of experience in building commissioning will be a latent problem. In addition, it is necessary to prepare for this, since it is impossible to properly respond in a timely manner to the contractor who must obtain final approval from a professional commissioning company before delivering the building to owner. In order to solve these problems, it is necessary to properly understand the submission documents and work system required by a professional commissioning company and to establish a work performance system to enable commissioning from the General contractor’s perspective.[5]

Therefore, the purpose of this paper is to develop a practical, systematic, professional template for commissioning for a large construction company. In addition, commissioning of buildings is the main subject of performance verification of Heating, Ventilating and Air Conditioning and Refrigeration (HVAC & R) systems that require equipment and control, so we focus on verification of HVAC & R. In order to create a template, the project was categorized into 4 phases, and the details of each phase are as follows.

Table 2. Creating template in each phase

Phase	Objective	Data
Plan	● Standard OPR template	● International proposal analysis
Design	● Design criteria ● Design checklist	● Design criteria and system requirement analysis ● OPR & BOD analysis
Construction	● Equipment/system performance verification template ● Commissioning manual / process template	● Function and standard manual of performance check ● Commissioning manual ● Commissioning process analysis
Warranty (Acceptance + Operation and maintenance (O&M))	● System and O&M manual	● Existing system / O&M manual analysis

2. Literature review

As the functions and performances of buildings have become more and more complicated in recent years, building commissioning has been widely applied as the perception that a step-by-step review and verification of whether a building is being designed, constructed, and operated is required to ensure that the building performs its expected performance. Building commissioning is a technique that applies the quality assurance process to the construction industry. [6] It is defined to verify that the needs of the owner are well reflected at each phase of construction. If appropriate commissioning is applied according to the characteristics of the building, it not only can satisfy the required performance of the building, but also helps to complete a healthy building through environment-friendly.

2.1 The type of commissioning

The building commissioning can be divided 5 categories and the contents are as follows.

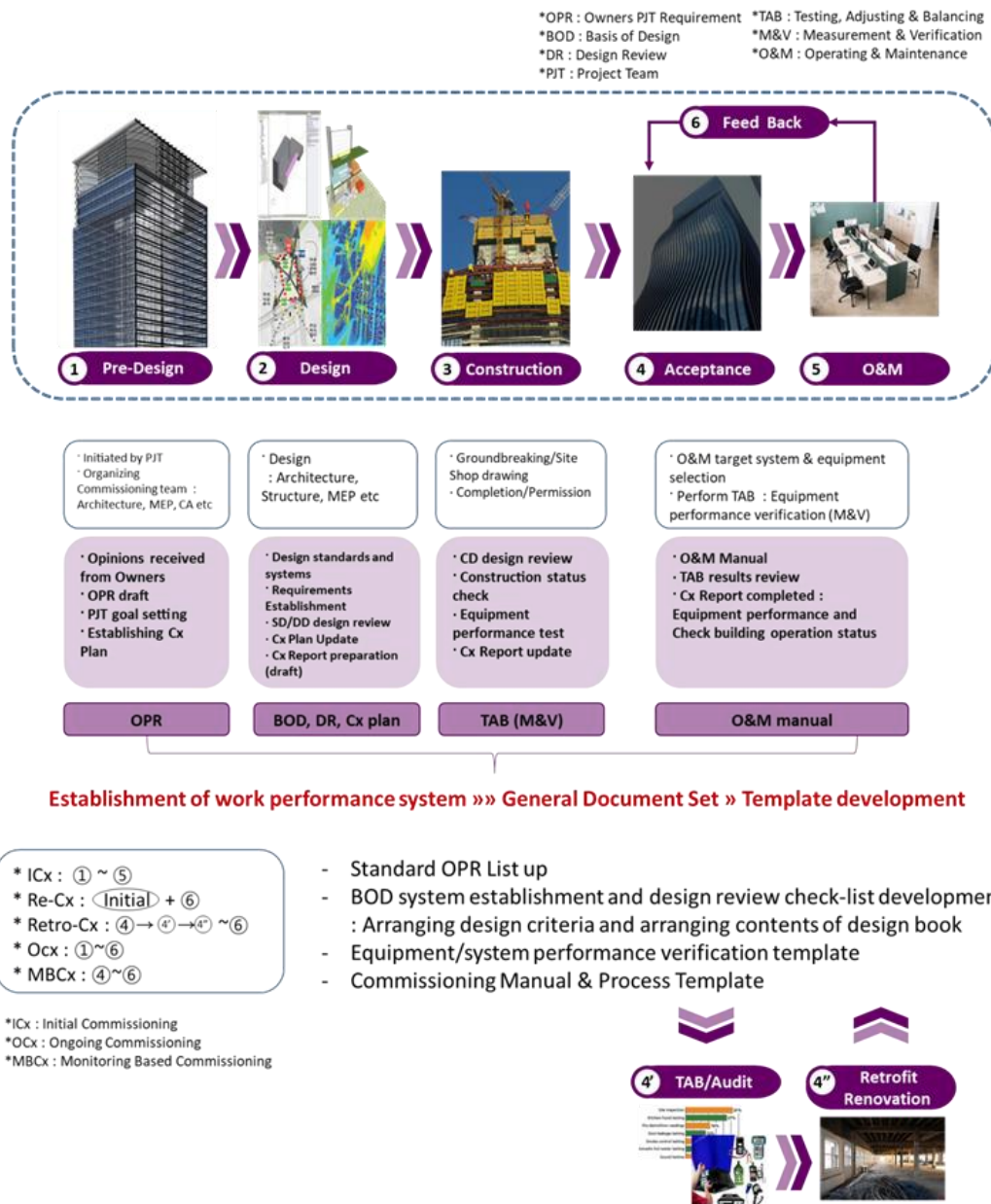


Figure 1. Type of commissioning, As-is vs To-be, and final objective of template

- (1) Initial commissioning (ICx) : Procedures performed for new buildings
- (2) Re-commissioning (Re-Cx) : Following ICx, when ownership of a building changes or operational problems are discovered
- (3) Retro-commissioning (Retro-Cx) : Procedures applied to existing buildings that have not been commissioned
- (4) Ongoing commissioning (OCx) : Procedure to verify that the target building maintains continuous performance
- (5) Monitoring based commissioning (MBCx) : A procedure similar to OCx that continuously maintains the building's system

2.2 The advantage of building commissioning

2.2.1 Expected effect

According to overseas studies, the average operating cost of commissioned buildings is 8 to 20% lower compared to those that do not. In addition, according to Altwies research [7], commissioning can reduce design changes by 87% and rebuild by 90%. Then, the total construction cost savings are 4 ~ 9%. And the advantages of stakeholder are as follows.

(1) Advantages of the owner

- Efficient operation and maintenance

- Failure frequency can be reduced
- (2) Advantages of architect
 - Equipment system meets the needs of the owner
 - Change management is possible
- (3) Advantage of contractor
 - Efficient construction management
 - Reduce defects

2.2.2 Commissioning cost

The cost of building commissioning is affected by the type of facility, the difficulty of construction, operating hours, and equipment level. Therefore, it is difficult to calculate the standardized cost, but the US PECE and LBNL provide examples of commissioning cost. [8-10] The contents are as follows.

(1) California Commissioning Guide

Table 3. Domestic and international guidelines and laws

Type of commissioning	Item	Service fee
Initial commissioning (ICx) [3]	Total ICx Cost	\$0.49~1.66 / sq.ft
		74~86% of total Cx Cost
	● CxA service fee	0.3~1.1% of total construction cost
	Component of ICx cost	Rate
	● Design review	18%
	● Construction Observation	14%
Re-Commissioning (Re-Cx) [4]		64%
	● Warranty	4%
	Total Re-Cx Cost	\$0.13~0.45 / sq.ft
	● CxA service fee	35~71% of total Re-Cx Cost
	Component of Re-Cx cost	Rate
	● Planning & Investigation	69%
	27%	
	4%	
	Reporting	

(2) APPA, Commissioning Handbook [11]

Table 4. Domestic and international guidelines and laws

Item	Service fee
Total Cx Cost [5]	\$0.15~0.6 / sq.ft
Commissioning member	Additional fee
Design company	\$0.025~0.01 / sq.ft
Construction company	\$0.10~0.30 / sq.ft
Operation company	\$0.025~0.20 / sq.ft

(3) ASHRAE Journal [12-13]

Table 5. Domestic and international guidelines and laws

Commissioned object system [6]	Cost
HVAC & Controls	2~3% of total construction cost
Electrical system	1~2% of total construction cost
HVAC, Controls and Electrical	0.5~1.5% of total construction cost

(4) GSA¹⁵ [14]

Table 6. Domestic and international guidelines and laws

Item	Service fee
Total Cx Cost [5]	\$0.15~0.6 / sq.ft
Commissioning member	Additional fee
Design company	\$0.025~0.01 / sq.ft
Construction company	\$0.10~0.30 / sq.ft
Operation company	\$0.025~0.20 / sq.ft

15. GSA : US general services administration

The GSA's commissioning guide includes the charts provided by PECCI, which are used to refer to the calculation of commissioning costs for various buildings.

(5) LANL (Los Alamos National Laboratory)

Table 7. Domestic and international guidelines and laws

Item	Cost
Entire building	0.5~1% of total construction cost
HVAC, Automated control system	1.5~2.5% of mechanical system
Electrical system	1~1.5% of electrical system
Measuring energy efficiency	\$0.23~0.28 / sq.ft

(6) CxA service fee

0.5~1.5% of construction cost is for CxA service fee in DOE, however, 1.25~2.25% is in The National Association of State Facilities Administrators (NASFA)[16,17].

2.3 Team building of commissioning

The general commissioning team is as follows. The essential members of the planning and design phases are Owner's representatives (OR), Commissioning Authority (CxA), Design Professional (DP), and in general, the OR can be Project manager (PM), occupants, user, facility manager, and O&M personal. Also, Architecture & Engineers (A/E) plays a DP role in a project. If you have CM, PM, Program manager (PM'), etc., they can participate as a commissioning member. The mandatory member of the construction phase is OR, CxA, DP, General contractor (GC), Vendor, CM, PM, and PM', and the vendor is the equipment manufacturer and installer. An essential member of the warranty phase consists of OR, CxA, DP, GC, Vendor, CM, PM, and PM', and etc. In relation to the HVAC & R system, the required members, additional members, and members who can participate if necessary are as follows.

3. Establish commissioning process

Although the project was initially defined in 4 phases, the contents of the warranty phase are complicated, so the Cx tasks were specifically divided by acceptance and O & M phase. The process standard is as follows. The main tasks were divided into steps, and abbreviations for each phase were entered as intermediate numbers so that they could be clearly recognized.

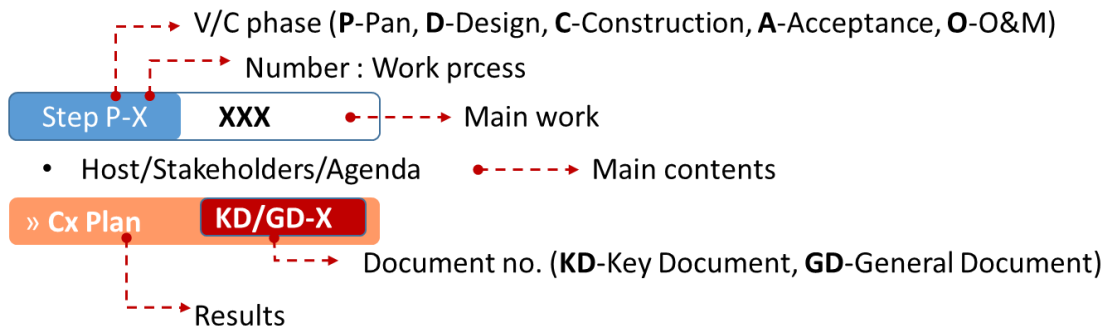


Figure 2. Process notation and numbering criteria

3.1. Plan phase

In the plan phase, "project proposal" starts under the authority of the owner. The first step of commissioning is from consisting of the "Cx team (commissioning team)". The commissioning team consists of

the ordering company, OR, CxA, A/E, CM, GC, and manufacturers. In the second step, the "Cx scope meeting" hosted by CxA is held. Through the meeting, each team member's Role and Responsibility (R&R) and work scope are determined. The determined R&R is reflected later in the Cx Spec. After the meeting, CxA drafts a Cx Plan (commissioning plan) and shares it with all members of the Cx team, including the owner. In addition, future business directions and plans will be determined. The third step is the "OPR Workshop", where the objectives of the project and the requirements of the owner are described under the authority of the OR or owner.

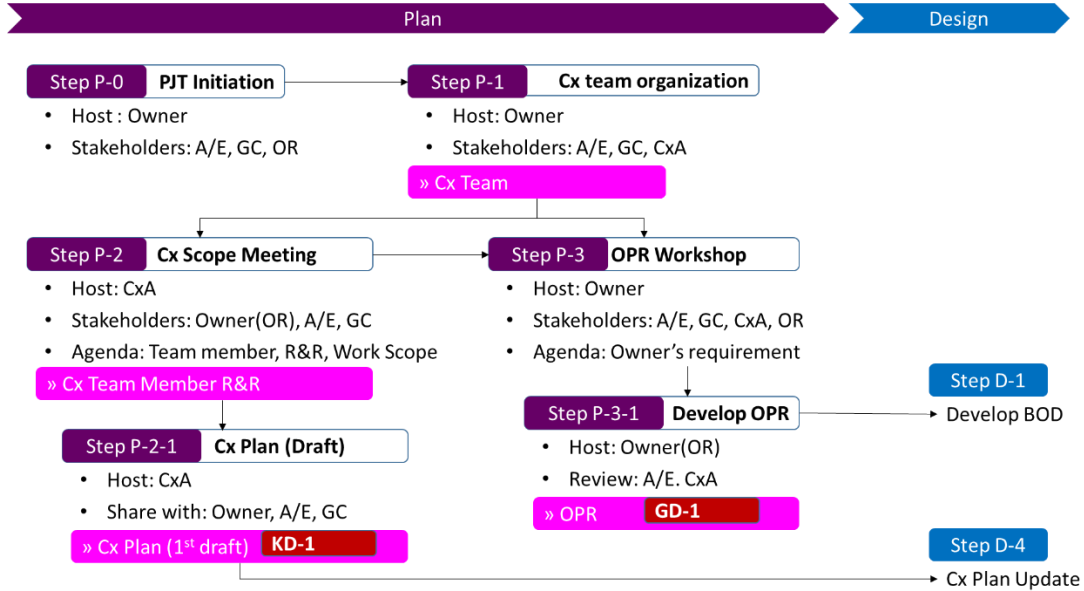


Figure 3. Commissioning process in Plan phase

3.2. Design phase

The commissioning process at the design phase is shown in Fig. 4.

The first step is "BOD development", where the A/E team is the main body and is creating design guidelines to meet OPR. Information such as system manuals and specifications is included in these guidelines.

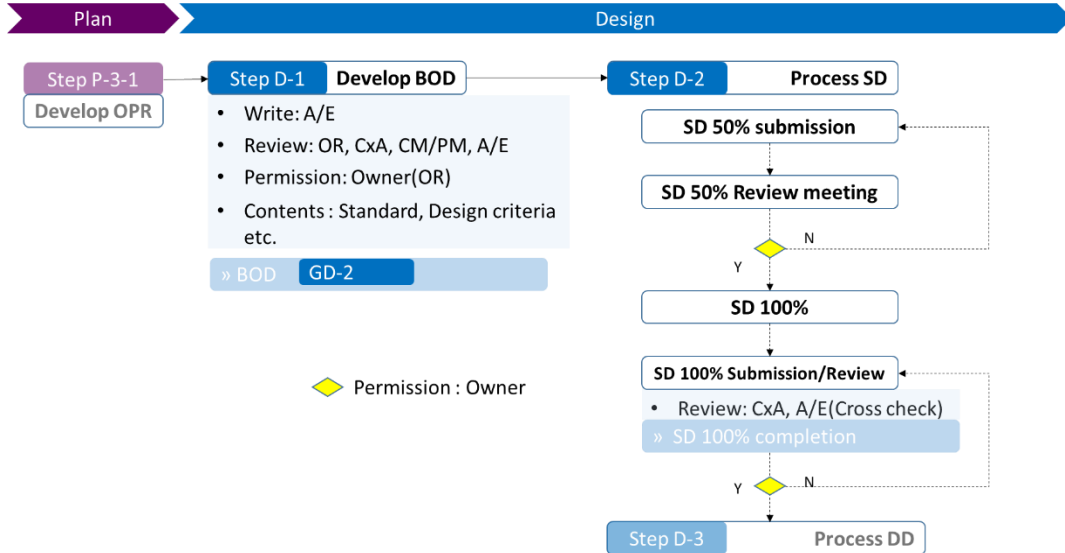


Figure 4. Commissioning process in Design phase

3.3. Construction phase

The commissioning process at the construction phase is shown in Fig. 5.

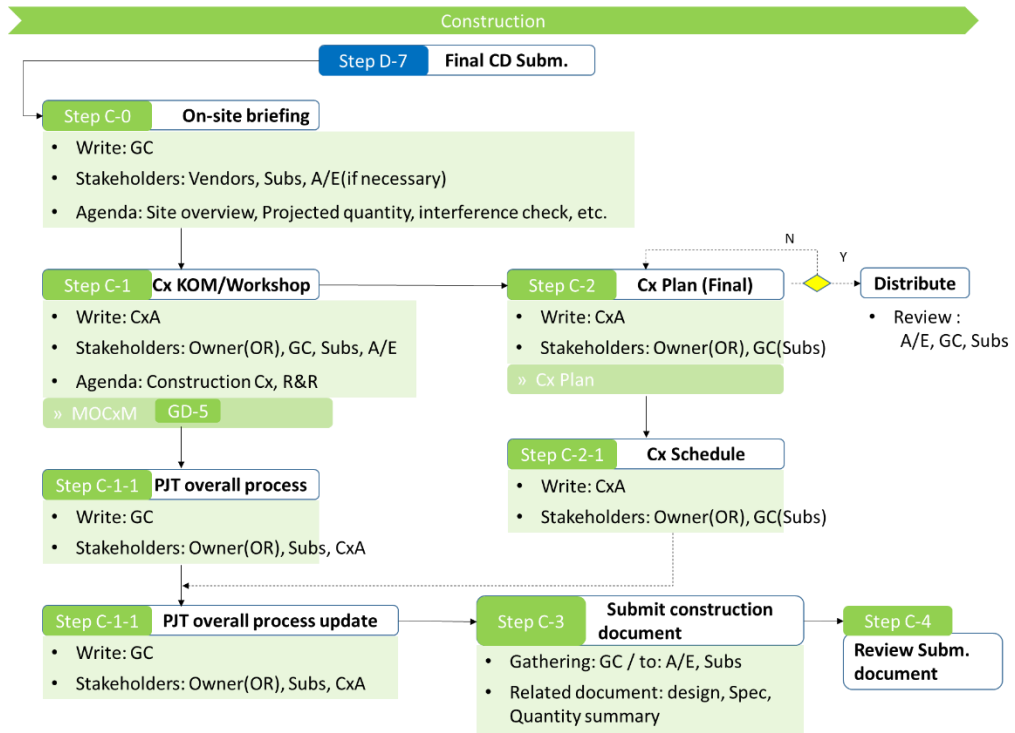


Figure 5. Commissioning process in Construction phase

3.4. Acceptance phase

The commissioning process at the acceptance phase is shown in Fig. 6.

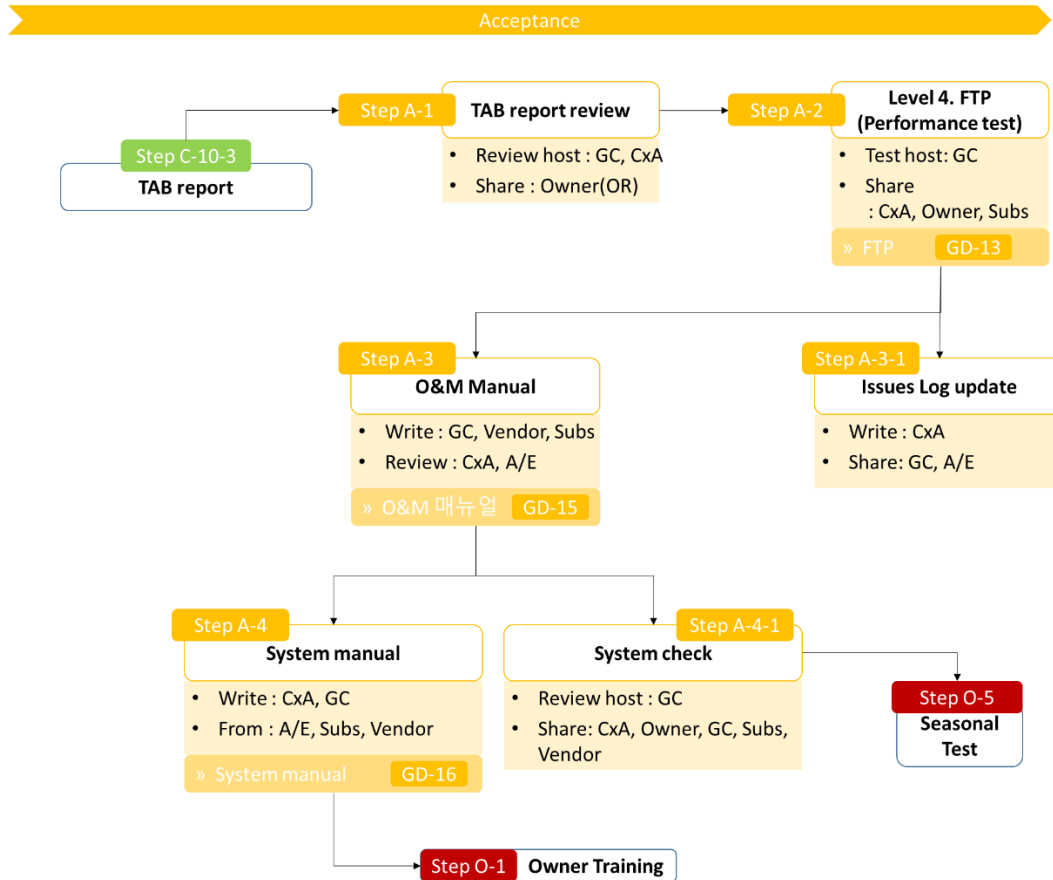


Figure 6. Commissioning process in Acceptance phase

3.5. O&M phase

The commissioning process at the O&M phase is shown in Fig. 7.

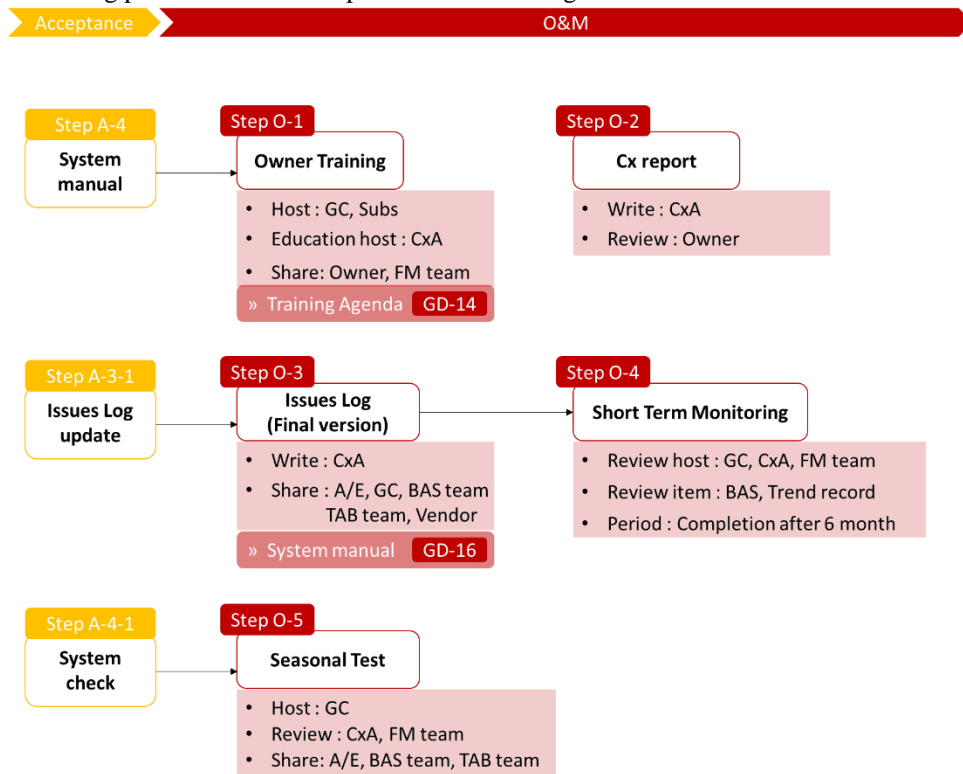


Figure 7. Commissioning process in O&M phase

4. Develop the commissioning template

The commissioning template is composed of key document and general document package. The key document is composed of Cx Plan and Cx Spec, which explain the commissioning process and R&R of team members, and the general document package is composed of documents that should be accomplished phase by phase.

4.1 Cx Plan

It is a plan that explains the overall business procedures and plans that are the basis for commissioning and describes the R&R of each participating participant. It should be revised to reflect the current status in each phase of design, construction, and O&M. It is written by CxA and shared with owner, OR, A/E, and GC. The main contents consist of 1) commissioning work, 2) R&R, and 3) commissioning schedule.

4.2 Cx spec.

This is a document that describes the terms and conditions of proceeding and R&R related to commissioning. This document should be revised to reflect the construction conditions. It is written by CxA and shared with Owner, OR, A/E, and GC. The main contents consist of 1) contract terms, 2) R&R, and 3) proceedings. The documents related to the Cx spec are as follows. 1) Sample test rating, 2) R&R/activity matrix, 3) Cx system selection matrix for each product, 4) Cross check item when applying integrated system

1) Sample test rating

ASHRAE proposes a random sampling technique for sample test ratings and a guide to select sampling rates in consideration of project characteristics. The Quality based sampling examples consist of complexity, criticality, length, owner's input, CxA, construction checklist, construction speed, and the amount of equipment. Final commissioning process testing consists of complexity, criticality, owner's input, and CxA. In addition, CxA can also adjust the rate of sample test ratings, and the rate can vary depending on the contract.

2) R&R matrix

Each of the US EPA, GSA, and NEBB organizations provides guidelines and standards of the R&R/Activity matrix. Therefore, you can select and use it according to the characteristics of the project.

3) Cx system selection matrix for each product

The Cx system selection matrix for each product consists of HVAC, plumbing system, Automatic temperature control system (ATC), building envelop, life safety systems, security and specialties. [14]

4) Cross check item when applying integrated system

Cross check item when applying integrated system is adopted by ASHRAE guideline. [15]

5. Conclusion

The purpose of this paper is to propose a template that can respond to commissioning from a large construction company. To respond the commissioning process, it should be established in each 5 categories such as ICx, Re-Cx, Retro-Cx, Ocx, and MBCx and each 5 phases such as plan, design, construction, acceptance, and O&M phase. The commissioning template is composed of key document and general document package. The key document is composed of Cx Plan and Cx Spec, which explain the commissioning process and R&R of team members, and the general document package is composed of documents that should be accomplished phase by phase such as Owner's project requirement (OPR), Basis of Design (BOD), Design review (DR), Sequence of Operation (SOO), Minute of commissioning meeting (MOCxM), Construction inspection report (CIR), Daily commissioning report (DCR), Issues log, Progress Log, Factory witness test (FWT) or Factory acceptance test (FAT), Vendor start-up, Pre-functional checklist (PFC), Functional test procedure (FTP), Training agenda, and O&M manual. And the previous research shows an owner can be saved 8-20% in operating cost through commissioning process. This paper showed how to prepare a template for documents corresponding to each step and each step for commissioning suifigfor large domestic construction companies. In addition, it is expected that this will not only improve the commissioning capacity of domestic construction companies, but also make a great contribution to the maintenance of owners.

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