

## **Defining Commissioning Process/Tools using Model Quality Control Matrix**

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### **Synopsis**

A Model Quality Control (MQC) matrix, which was originally introduced by the Netherlands delegate at the IEA Annex 40 (Commissioning of Buildings and HVAC Systems for Improved Energy Performance) meeting, has been developed by authors into a tool to define commissioning process either in general process or in specific project's process. It is used to define most of the necessary procedures required for commissioning authority as well as commissioning-related parties during the building production stage and operation stage. The matrix was structured on the most popular software, the MS-Excel, consisting of menu sheet, table of contents sheet, summary sheet, detail input sheet, and database. The detailed input sheet is for inputting detailed items, specifications and indices for linked sites in four layers. It is used to cite and/or link with required documents, documenting formats/templates and with technical tool information or directly tool itself to run a program. Moreover, the detailed item is linked to a related reference file, reference documents, URLs, or e-mail addresses; so it is easy to access the information for commissioning process.

Created MQC can grasp the all aspects of the commissioning work in production and operation stages, and it becomes easy to check required actions and obtain necessary information. This structure is not convenient to look at in the printed form because of multi-layer structure, in which huge and various contents of commissioning works are covered. Also, MQC tool is very useful to operate in actual business with customization to specific projects or specific kinds of commissioning objects such as commissioning of indoor air quality for residential houses, commissioning of thermal storage systems, commissioning of critical buildings, etc.

### **About the Authors**

Nobuo Nakahara is a professor emeritus of Nagoya University and president of Nakahara Laboratory, Environmental Syst.-Tech. He has the wide range of research experience and unparalleled contribution on Japanese HVAC engineering. He has initiated active building commissioning activities in Japan, has chaired the SHASE Commissioning Committee to

establish the Japanese Guideline for HVAC Commissioning Process and is chairing Japan committee for ECBCS/IEA Annex 40. He was graduated from Architectural Department of Tokyo University in 1957, Dr. of Engineering.

Katsuhiro Kamitani is a research engineer of the Technical Research Center, Tonets Corporation, one of the major HVAC system contractors in Japan. He is a mechanical engineer of HVAC systems. He also takes a part of IEA Annex40 research group as a Japanese committee member and has developed this MQC tool software. He was graduated from the Department of Physics, Science University of Tokyo.

Hajime Onojima is a group leader of the Building Information System Group in the Mechanical and Electrical Technology Department, Obayashi Corporation, one of the major general contractors in Japan. He has been involved in the steering committee to establish the Japanese Guideline for HVAC Commissioning Process for SHASE. He also takes a part of IEA Annex 40 research group as a Japanese committee member. He was graduated from Architectural Department of Waseda University, has a Ph. D. in Engineering from the Waseda University.

## **Introduction**

Recent building construction process is quite complicated for the conventional control process, first of all because of wide range of variation among building projects from the building purpose to owner's requirements' points of view. The owner's requirements and criteria might often change dramatically because of not only financial or social situations, but also just a personnel reassessment. The second reason is the construction project requires involvement of many suppliers, manufacturers, consultants and contractors. Construction manager must take care of and manage the all sorts of problem between them. The third, many regulations, laws and standards must be considered on construction process. Finally, the critical rises of energy issues and environmental subjects, from the indoor comfort to the global warming-up, and complicated interactions among professional engineering have been emerged.

Therefore, commissioning process has to also cover very wide range of construction process. Especially each HVAC system is a complex of components and equipment. Even all of equipments work perfectly, HVAC system could have a problem because it must operate as a total system. Commissioning of HVAC systems requires not only components commissioning but also systematic commissioning of total systems.

Recently, several commissioning tools are proposed and applied in a real application. However, most of them are for limited use from the viewpoint of commissioning control tool of the total process. A model tool is necessary to describe the all range commissioning process and tools. In the present paper, software called as Model Quality Control Matrix is introduced as the tool to describe a Standard Model Commissioning Process, SMCxP, and for customized use for any specific projects.

This MQC matrix with relevant information and database basically gives CA almost all the information throughout the initial commissioning process when, where, who, what, why and how

to manage and control in a standardized model commissioning as well as customized commissioning for any specific project. Wide range of application is possible for the MQC matrix not only for commissioning process but also for any construction related information to be documented, integrated and archived systematically. Many kinds of guidelines, manuals and specification could also be the object of application.

Model Quality Control (MQC) Matrix is proposed from the Netherlands in IEA Annex 40 (Commissioning of Buildings and HVAC Systems for Improved Energy Performance: <http://www.commissioning-hvac.org/default.asp>) meeting to describe the Commissioning process of HVAC systems. IEA Annex 40 is the international cooperation program under International Energy Agency, Energy Conservation in Buildings and Community Systems Program. The objective of the Annex is to develop, validate and document tools for commissioning buildings and building services that will help facilitate the achievement of goal. These tools will include guidelines on commissioning procedures and recommendations for improving commissioning processes, as well as prototype software that could be implemented in stand-alone tools and/or embedded in building energy management systems (BEMS).

## Model Quality Control Matrix

Model Quality Control (MQC) Matrix is a tool for structural approach for commissioning of HVAC systems and covers all phases and aspects of projects. In the Netherlands, general models of building services are already developed (ISSO publication 50 for heating, ISSO publication 61 for domestic ventilation).<sup>1</sup>

This matrix has a hierarchical structure, shown on Figure A. The first layer is, as shown in Figure B, the commissioning process sheet describing commissioning process in horizontal direction and commissioning aspects in vertical direction. The second layer is the comprehensive table of commissioning related matter.

Each cell of this table has the multiple contents.

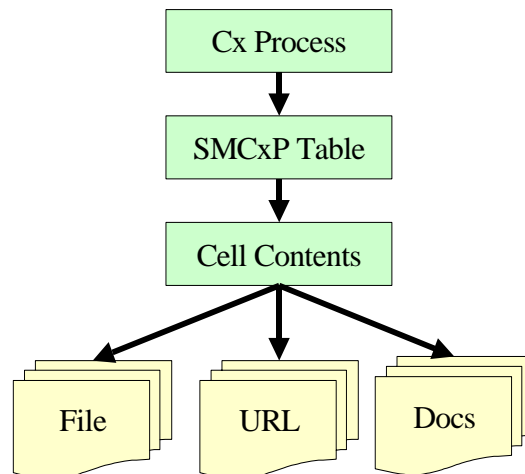


Figure A: Structure of MQC Matrix.

Commissioning Matrix		Production Stage						
		Program Phase (Pre- Design Phase)		Design Phase		Elabolation Phase	Construction Phase	
Instructions		MASTER MODE						
TYPE : W X Non-Residential Building		Program Step	Planning Step	Preliminary Design Step	Working Design Step	Elabolation Step	Construction Step	Acceptance Step
aspect	Definition	Phase Keyword						
		Phase Definition						
		Step Definition						
		CA's Role						
	Actions							
	Organization							
	Requirements	Standards/ Regulations						
		Performance/ Criterior						
	Commissioning Tools	Documentation Tools						
		Technical Tools						
		Communication Tools						
	Purchase/ Finance	Purchase (outsourcing, hiring)						
		Funding						
	Outcome/ Documentation							
	Others							

Figure B: MQC Matrix.

### Commissioning Process Phases and Steps

Commissioning process is divided into several phases which are further divided into several steps for the sake of defining commissioning process as follows.<sup>2</sup>

- Pre-Design Phase, or Program Phase*  
 Pre-Design Phase is the first phase of initial commissioning process. First, the owner spreads out the project concept and makes the owner’s project requirement, or OPR, with the help of commissioning authority, or CA. The program step is defined as before hiring CA and the planning step is defined as after CA hired.
- Design Phase*  
 Design Phase begins with making schematic planning documents and ends with completion of design documents and with handing over them to the owner. This phase is divided into the preliminary design step and the working design step with the border defined by submission of preliminary design document. The degree of completion of it compared with working design document is widely varied depending on the contract between design professional and client.
- Elaboration Phase*  
 Elaboration Phase is a transitional phase between the completion of design works and the beginning of construction. During this phase, the completion of the construction documents, the bidding, the assessing and the contracting for the construction order are performed. The phase is not further divided into any steps.
- Construction Phase*  
 In the construction phase, the contract based on the design documents is performs, and the construction of building starts. Hereafter the construction completes under the

construction supervision and/or construction manager and the contractor hands-over it to the building owner at the end of construction phase. The testing, adjusting and start-ups, or TAS<sup>a</sup>, are performed by contractors at the end of the construction step before the followed functional performance test, or FPT, led by CA at the acceptance step.

- *Occupancy & Operation Phase*

Occupancy & operation phase is a phase after building systems were completed and handed over to the owner. In this phase, as the functional performance test of building systems were already performed and maintenance staffs were educated and trained at the precedent phase, systems are to be operated properly. However, in case of systems that need seasonal commissioning such as HVAC systems, the initial performance of the systems will be fixed after one year of operation experience, which includes four seasons, and functional performance test as well TAS continues during post-acceptance step.

## Commissioning Aspects

The aspect that is related with commissioning process is classified as follows in MQC matrix.

- *Definition*

This aspect includes the definition of each commissioning phases and steps including keywords. The CA's role in each step is also described. The key player's role in each step other than CA is also listed in each aspect for reference in order for users of MQC matrix to understand peripheral important jobs done by other players in construction process.

- *Action*

All sorts of action relating construction process will be listed in this aspect. The items can be divided into the commissioning related actions and non-related ones.

- *Organization*

The participants for the relevant commissioning process on each step are to be described. Sometimes it includes contact address to them.

- *Requirements*

Requirements are classified into legal requirements and quality requirements, both of which shall be important information on defining OPR. The standard/regulations and performance criteria on energy and environment will be shown on this aspect.

- *Commissioning Tools*

Documentation tools, technical tools and communication tools for commissioning will be listed.

- *Purchase/Finance*

Outsourcing and funding aspects will be included.

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<sup>a</sup> TAS, testing adjusting and start-ups, is defined to meet with construction custom in Japan where TAB, equipments' start-up and synthesized test operation of subsystems and total system are performed by HVAC contractors, not by the dedicated TAB contractors as in USA.

- *Outcome/Documentation*  
The output of the commissioning process like OPR, issue logs, commissioning plan and commissioning specifications, together with non-commissioning related documents such as design documents will be listed here.
- *Others*  
Any other information that could not be classified into any kind of above-mentioned aspects will be filled out.

## **Description of the MQC Tool Software**

MQC is a non-technical commissioning control tool, which has the functions to define the commissioning process for any Standard Model Commissioning and to be used for customization to specific project as the database including all the information during commissioning process by overriding, deleting and/or adding. The tool was developed with MS-Excel using macro program, one of the most popular software. The developed function and composition as a MS-Excel file are described, hereafter.

### **Composition of Excel File**

Five sheets compose the developed Excel file of MQC tool. First sheet is a “Cx Process” sheet as shown in Figure C, on which all phases and aspects defined as a commissioning process can be viewed. By selecting and double clicking an arbitrary cell for viewing the cell contents, key information and list of items appears for chosen intersection of the step and aspect.

The second sheet is a “Select” sheet. The sheet has the function for the table of contents. Users can jump to the third sheet that includes comprehensive information of the selected cell on the Cx process sheet. The third sheet as shown in Figure D is called “Subjects” sheet, or a summary sheet. Users can add, delete, insert and/or modify the contents with any necessary information to obtain SMCxP or dedicated commissioning process for a specific project.

The fourth sheet is called “Cell Contents” sheet as shown in Figure E. More detailed information, which is described on “Subject” sheet are organized on this sheet. This sheet has the function to link to computerized documents, URLs or e-mail addresses.

The final sheet is “Instruction” sheet. This sheet is an on-line manual how to use MQC tool.

Commissioning Matrix		Production Stage						Operation & Maintenance Stage		
Instructions		Program Phase (Pre-Design Phase)		Design Phase	Elaboration Phase	Construction Phase		Operation Phase (Occupancy and Operations Phase)		
TYPE IV - V Non-Residential Building		Program Step	Planning Step	Preliminary Design Step	Working Design Step	Elaboration Step	Construction Step	Acceptance Step	Post-Acceptance Step	Post-Post-Acceptance Step
Definition	Phase Keyword									
	Phase Definition									
	Step Definition									
	CA's Role									
Actions										
Organization										
Requirements	Standards/Regulations									
	Performance/Criteria									
	Documentation Tools									
Commissioning Tools	Technical Tools									
	Communication Tools									
	Purchase/Finance (outsourcing, hiring)									
Purchase/Finance	Funding									
	Outcome/Documentation									
Others										

Figure C: "Cx Process" Sheet

Commissioning Matrix		TYPE IV - V Non-Residential Building	
Roman letters: CA's role, action and Cx related events		Preliminary Design Step	
Italic letters: Principal players' role, action and Cx related events among Cx Related Parties during the		Preliminary Design Step	
Standard Model Commissioning Plan		Preliminary Design Step	
Detailed Preview		Preliminary Design Step	
Requirements		Standards/Regulations	
		Building Code and Regulation	
		Fire Code and Regulation	
		Public Building Regulation (Green Building)	
		Energy Conservation Regulations	
		JIS (Japanese Industrial Standard)	
		ISO	
		JASS/HASS (Academic Standards for Architecture and HVAC)	
		Licenses and Intellectual Property	
		Indoor Environmental Criteria (IAQ, VDC)	
		Economic Performance (First C, Operating C, Life Cycle C)	
		Environmental Load (CO2, Waste, Energy)	

Figure D: "Subject" Sheet

phase	input1	input2	object
Preliminary Design Step	Requirements	Performance/Criteria	Green Building Rating System

cell contents	specification	specification2	URL	MAIL	Other Files
LEED, USA	Introduction				<a href="#">Introduction.pdf</a>
USGBC, Japan	Energy and atmosphere				<a href="#">Energy and Atmosphere.pdf</a>
	Introduction				<a href="#">Introduction.pdf</a>

**Figure E: “Cell Contents” Sheet**

## Operation of MQC

The developed MQC tool has two functions. First one is the organized database management of commissioning process to accomplish commissioning project. Using this function, users can describe the information on the blank MQC and define the commissioning process. The other is browsing the selected information from the commissioning process database. User can browse the necessary information for commissioning.

### Start-up MQC

At start-up of the MQC Excel file with enabling macro, user should select either “User Mode” or “Master Mode” (Figure F). Usually the “User Mode” shall be selected for commissioning purposes to input, edit and browse cell contents. “Master Mode” is the mode for manipulation of database, for example integrating the multiple database, etc. only to be used by whoever have IT professional knowledge.

### Defining MQC

After start-up of the MQC, user defines information of commissioning process on “Subject” sheet. The menu box, which will appear by double-clicking, is used for information inputting (Figure G). By selecting “New Input” button showed in the menu box user can input the information into the cell. By double clicking any other cell the inputted information will be registered on the database. Thus, the user can modify, copy or delete the information in the same manner. When user selects “Detailed Input”, detailed cell contents appears and now he can define more detailed contents about inputted information (Figure H). These contents can be linked with the computerized documents, URLs or e-mail addresses. This function uses the hyperlink function on the MS-Excel.



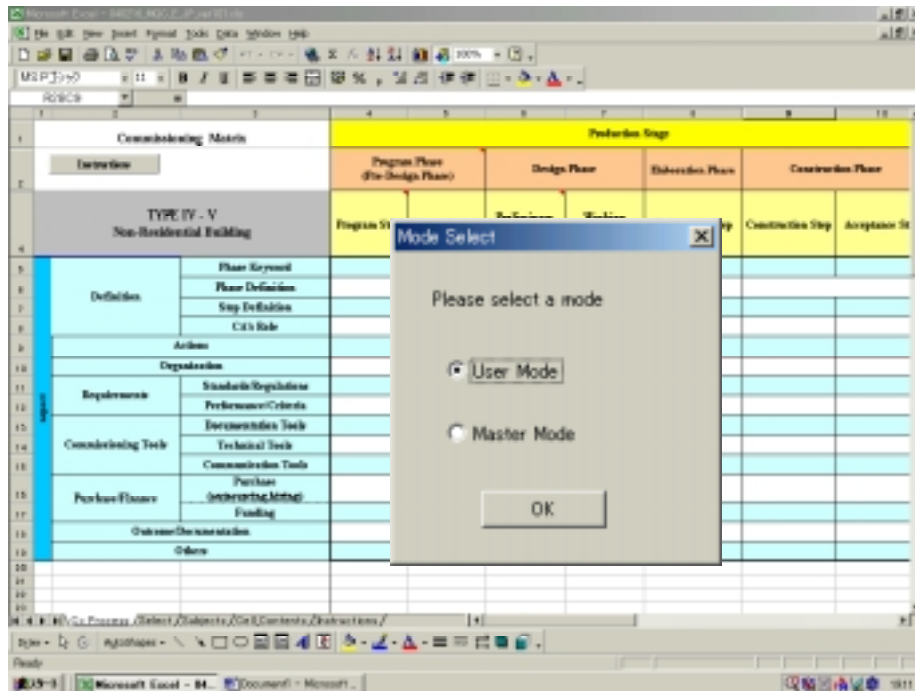


Figure F: Mode Select Window

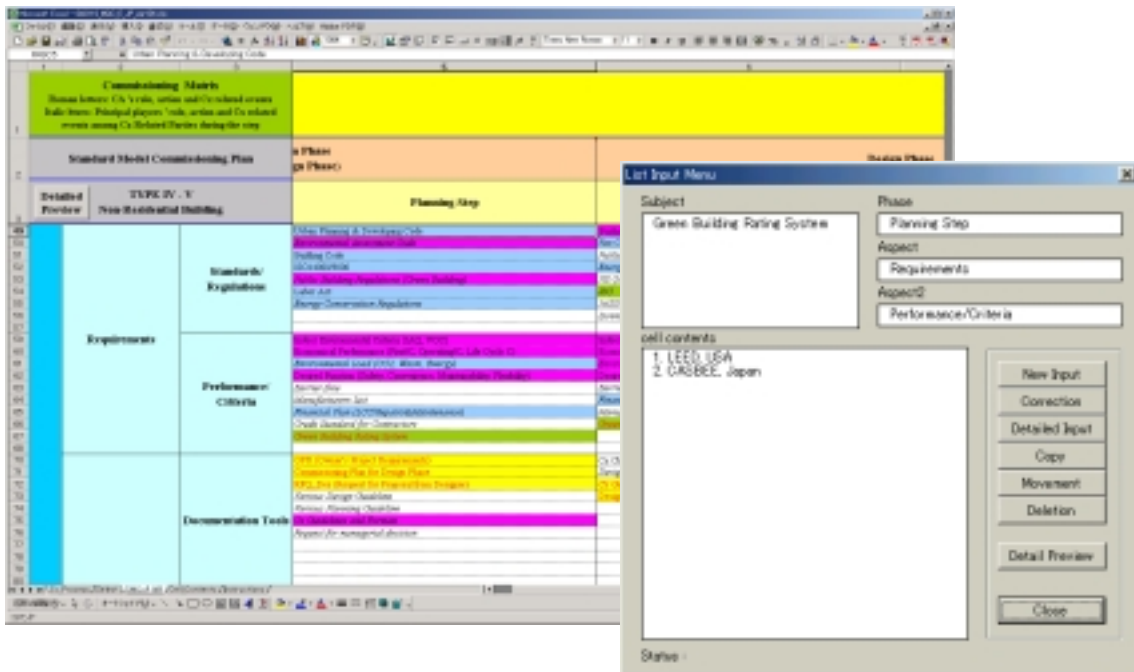


Figure G: Menu Box Window on "Subject" Sheet

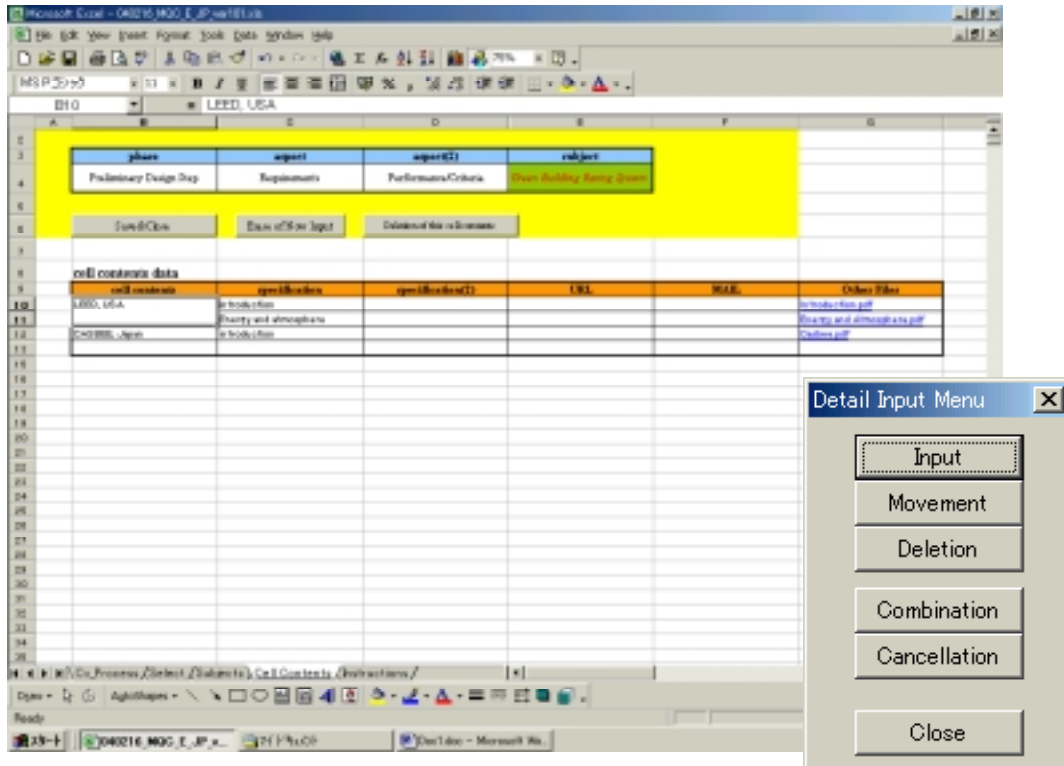


Figure H: Menu Box Window on “Cell Contents

### Browsing Information

The most normal operation for browsing the information is the function of “Cx Process” sheet. As shown in Figure I, user shall select and double-click an intersection of a phase and aspect on the “Cx Process” sheet. Then detailed key information of the database, that is, the first column of the cell contents sheet of the desired cell appears on the left window of menu box. There is a window to select phases and aspects at the right side of menu box. User can browse the different information by changing phases and aspects from here. Also, using “Select: Subject” window at right center user can obtain more detailed information included in cell contents sheet by clicking “Detail review” button.

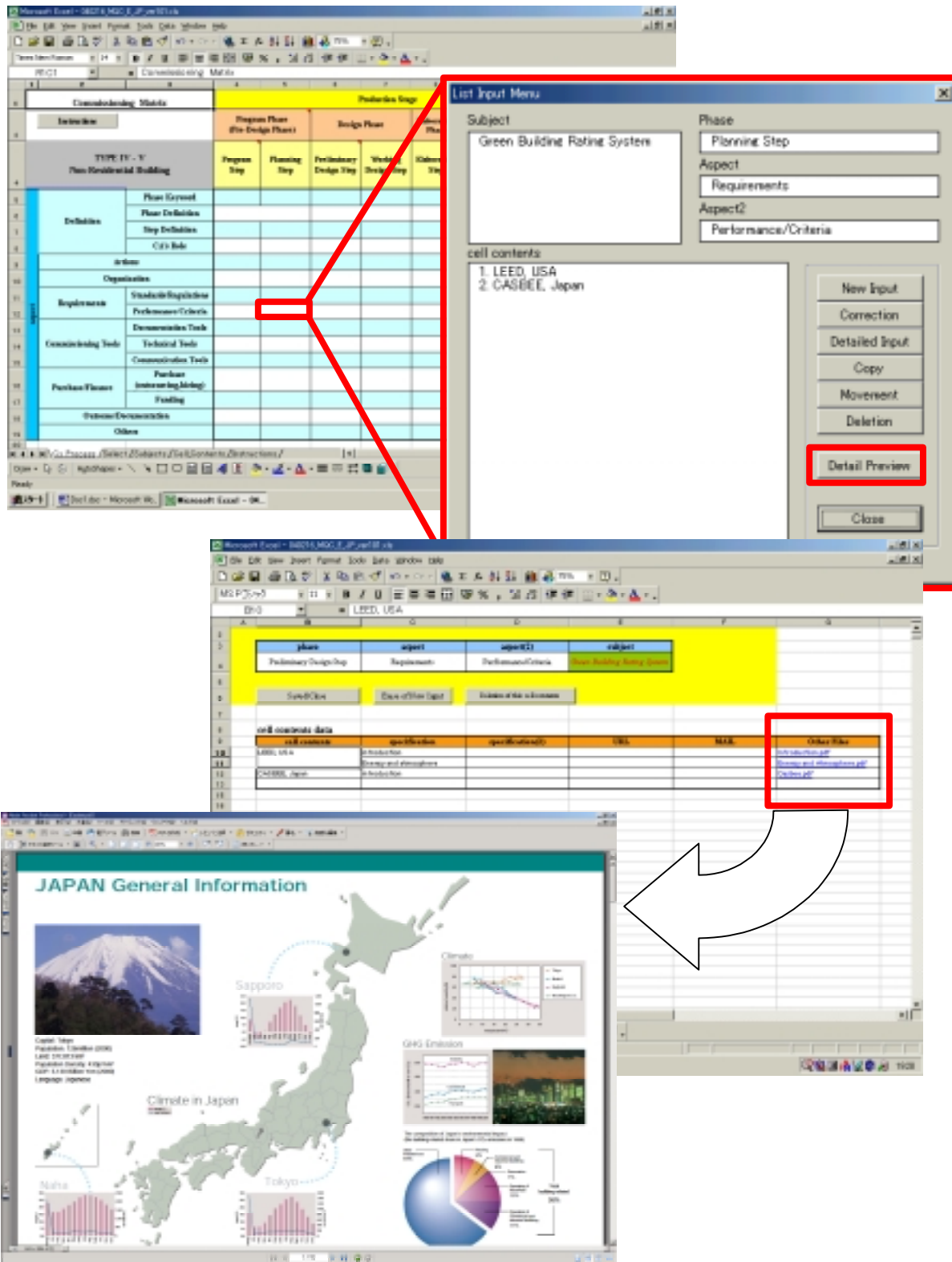


Figure I: Information Browsing Flow

## Application

This software tool can be used for several purposes. All kinds of information can be linked from the top sheet by way of the selected matrix cell. All the cell contents should be replaced according to users' social and technical environment, if necessary. Example descriptions shown in the present paper are based on Japanese way of construction business and regulations, which are not so much different from international one, authors believe, for non-residential complex buildings.

## Electronic Commissioning Guideline

If all the cell contents, for example all of HVAC commissioning process guideline, are fully inputted, then electric commissioning guidelines and tools are obtained in a single MQC matrix with the full of database and technical tools included. Existing information, documents and formats are cited and/or linked directly in or from the cell contents. Users can find whatever they wants, whenever the phase is and whoever they is, that is, the CAs, owners, design professionals or contractors.

## Project Oriented Model Quality Control Matrix

Another example is customization of MQC for any specific project. Specific name, contact address, email address and likes of each commissioning team shall be filled in. The cell contents include commissioning tools, documents which were used in the projects and test reports, etc. The customized electronic MQC also includes commissioning plan, commissioning specification, commissioning report and any other products of commissioning implementation. Commissioning related parties can also describe whatever they have done in connection with commissioning of specified projects.

## Conclusion

Authors' creation of MQC commissioning control tool is useful enough to overview, document and store products of any commissioning projects and to define SMCxP, making it easy to check the required information. As this structure of multi-layers is inconvenient for printed documents, PC-oriented electronic is the most suitable and easiest to use. MQC tool is also useful to operate in actual business with customization to specific projects or specific kinds of commissioning objects such as commissioning of indoor air quality for residential houses, commissioning of thermal storage systems, commissioning of critical buildings, etc.

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<sup>1</sup> P. Op't Veld, et.al: Model Quality Control (MQC) and Commissioning for HVAC Systems, Working Paper of Scheveningen meeting of Annex 40, ECBCS, IEA, April, 2001

<sup>2</sup> Y. Akashi, et.al: Draft of Glossary in Annex 40, Working Paper of Berkeley meeting of Annex 40, ECBCS, IEA, October, 2003