APPLICATION OF REVISED QUALITY FUNCTION DEVELOPMENT TO BUILDING CONSTRUCTION PROJECT

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ABSTRACT: One of the major interests of the Japanese public clients applying ISO9000s is to mitigate their own burden generated by the surveillance of works. It is, however, quite a sensitive issue whether the surveillance of works can be mitigated successfully without jeopardizing the level of quality of the buildings, because the surveillance is one of the most important jobs for securing the quality demanded by the clients. This paper introduces our newly developed computer aided decision-making supporting system that optimizes the trade-off relation between the mitigation of the surveillance of works and the assurance of the quality. The system is called Revised Quality Function Development (R-QFD), which we modified and revised QFD method. R-QFD was applied to a real project and the effectiveness of the method was proved.

KEYWORDS: ISO9000s, QFD, R-QFD, computer aided, decision-making

1. INTRODUCTION

In these several years, Japanese public clients have begun to examine the effectiveness of applying ISO9000s quality management system (Hereafter, it is abbreviated as ISO) to building construction projects. Ministry of Construction (MOC) declared to apply ISO at the pre-qualification stage of the projects. (Hereafter, it is called ISO projects) In the year of 2000, twenty projects procured by MOC are to be contracted with the contractors through open competitive bidding. Not only MOC, but also some other public clients, such as Ministry of Posts and Telecommunications (MPT) or self –governing bodies, are decided to apply ISO on their own projects procurement. The number of construction companies that obtain ISO certification increases rapidly in accordance with the increase in the number of public clients applying ISO as shown in figure 1.

One of the major interests of the public clients is to mitigate their own burden generated by the surveillance of works. Because the contractors that obtain ISO certification (hereafter, it is called ISO contractors) can be thought to be reliable in securing quality, the clients may be able to rely on the ability of the ISO contractors' surveillance.

It is, however, quite a sensitive issue whether the surveillance can be mitigated successfully without jeopardising the level of the quality of the buildings, because the surveillance is one of the most important jobs for securing the quality demanded by the clients. It is therefore crucial discussion for the clients to know which supervisory tasks can be omitted and which can't be.

This paper introduces our newly developed computer aided decision-making supporting system that optimises the trade-off relation between the mitigation of the surveillance and the assurance of the quality. The system is called Revised Quality Function Development (R-QFD), which we modified and revised QFD method. R-QFD was applied to a newly built post office whose client is Ministry of Posts and Telecommunications (MPT).

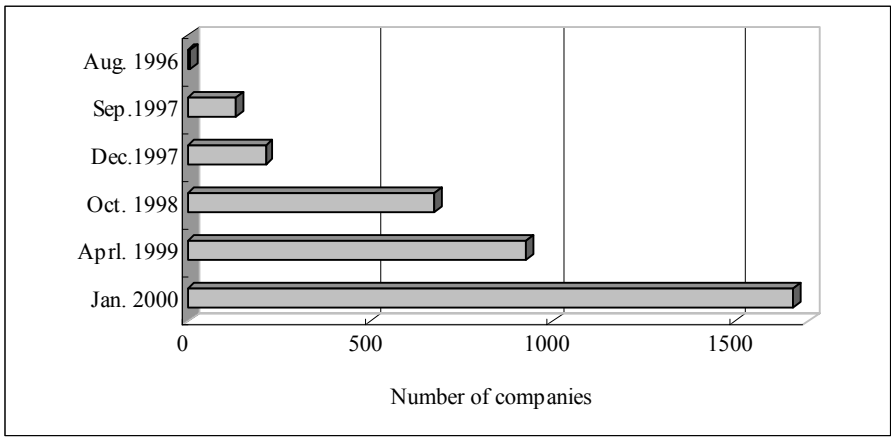

Figure1. Number of companies certified ISO9000s in Japan

2. BACKGROUND

2.1 Needs for mitigating the supervisory tasks

In general, Japanese public construction projects have two managements that are executed by the supervisory personnel belonging to a public client and the superintendent belonging to a contractor. Both managements try to assure the required quality in terms of their obligation and profit. The check and balance between these two managements are thought to be effective system for construction management as far as the allotment of tasks between the clients and the contractors are clearly defined. But it is said that the clients and the contractor execute the same tasks in many cases.

For example, two managements sometimes generate the inefficient aspect that is called "the double inspection". The contractors have their own inspection regulations regardless of requirements by the clients. So the contractors execute inspection without the clients order anyway. Usually, the items of inspection or the format of inspection sheet are different between the clients and the contractor. That means it is possible for the contractors to execute two kinds of inspections, nevertheless of the fact that the content of these two inspections are almost the same.

Considering the fact mentioned above, it is profitable both for the clients and the contractors to mitigate the surveillance of works. The profit of the clients is a laborsaving by omission of surveillance of works. The profit of the contractors is a laborsaving by omission of submitting project documents.

2.2 Needs for applying QFD

Yoji Akao initially developed QFD in Japan in 1966. Akao (1990) mentioned in his book that QFD is a method for developing a design quality aimed at satisfying the consumer and then translating the consumer's demand into design targets and major quality assurance points to be used throughout the production phase [1]. QFD have been applied on many industries such as automotive, chemical, aerospace, education, and so forth.

In construction industry, QFD are though to be a powerful toll of the project management [2][3]. Antti Lakka (1996) says, "QFD is a tool of, especially, the project manager when applied to construction projects. Its greatest advantage is that it provides the project manager with a systematic method of compiling and analyzing the customers needs ."

In this paper, R-QFD is applied to a building construction project for incorporating the needs of a client and a contractor to assure the required quality. It should be noted that R-QFD is applied at construction phase when the design is all defined. The client's needs are to

assure the specification of the defined design. The main interest of R-QFD is, therefore, the surveillance of woks, which doesn't include design development.

QFD is divided into two concepts. First concept is called QFD at wide sense that includes design development, and second concept is called QFD at narrow sense that includes engineering tasks. In this paper, QFD at narrow sense are treated. Hereafter, the word "QFD" is used as QFD at narrow sense.

3. DEVELOPMENT OF R-QFD

3.1 Concept of R-QFD

R-QFD is not a typical QFD in that some methods including QFD are mixed for the sake of practical application on the surveillance of works. The mixed methods are Relevance Matrix and Assurance Plan. Relevance Matrix is one of the evaluation methods by using matrix. Assurance Plan is a new idea introduced in this paper that is developed by modifying quality plan. ("Quality plan" is a typical idea in QFD.)

R-QFD consists of two major parts. One is the part of "quality function development drawing", and another is the part of "flow chart to define surveillance types". The concept is as shown in figure 2.

3.1.1 Quality function development drawing

The upper side of figure 2 shows quality function development drawing. The drawing consists of three matrixes (matrix 1, 2 and 3) and two tables (table 1 and 2). Left side of the drawing, that includes Matrix 1,2 and table1, clarifies two aspects of a client's requirement. One is clarified as the priority of assurance items. That is, which assurance item is more important than others for the client? Another requirement is clarified as the priority of

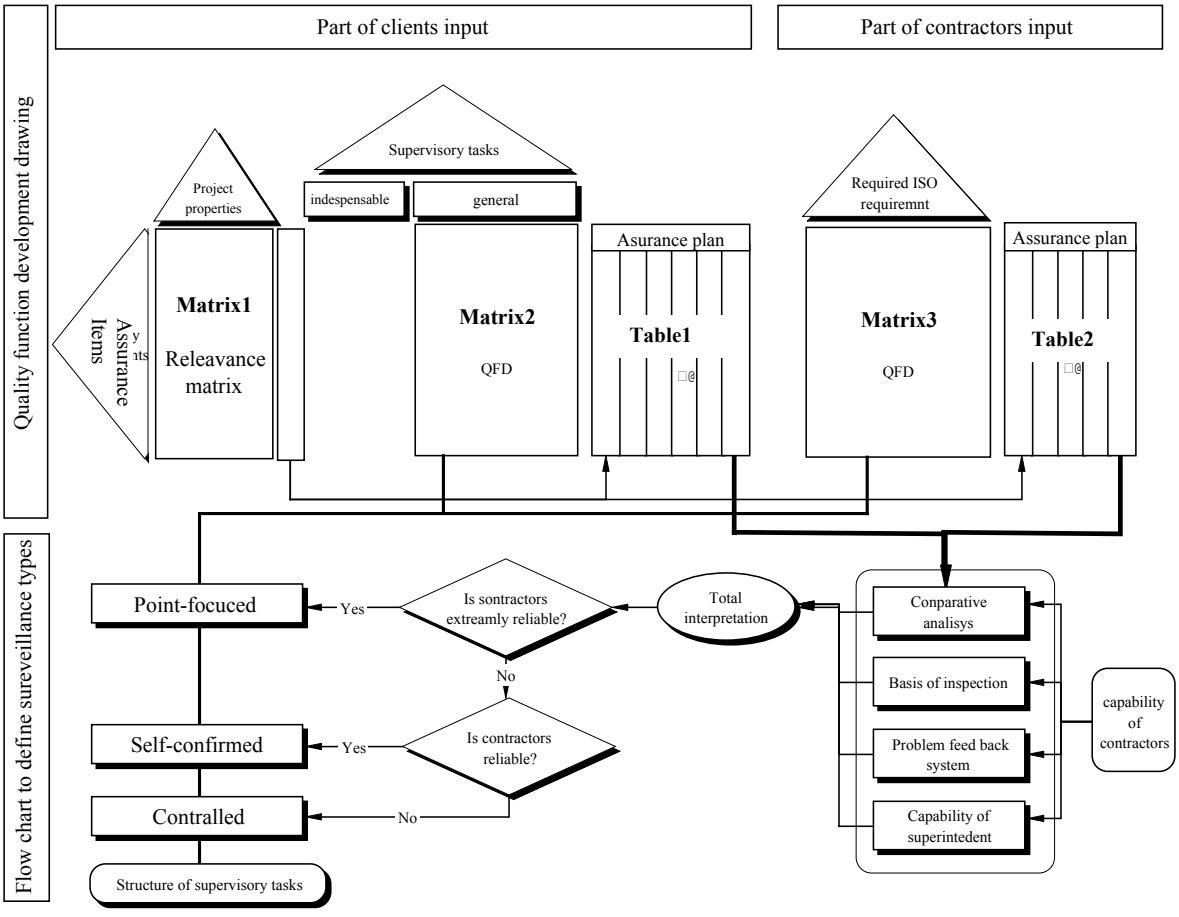

Figure2. Concept of R-QFD

supervisory tasks. That is, which supervisory task is more important than others for the client? Right side of the drawing, that includes matrix3 and table2, clarifies two aspects of a contractor's intention. One intention is clarified as the priority of assurance items. That is, which quality element is more important than others for the contractor? Another intention is clarified as the priority of ISO required elements. That is, which is more important ISO required element than others for the contractor. The idea mentioned above is shown in figure 3.

3.1.2 Flow chart to define surveillance types

The lower side of figure 2 shows flow chart to define both surveillance types and structure of supervisory tasks. The surveillance types are divided into three classifications. The first type is called "point-focused type". The second type is called "self-confirmed type". The third type is called "controlled type".

If the point-focused type is defined, the client can be dependent on the contractor in the most supervisory tasks. The client should execute only a few supervisory tasks that are focused as indispensable obligations of the client. If the self confirmed type is defined, the client's supervisory tasks that can be mitigated are negotiated between the client and the contractor. The mitigated tasks are to be executed by the contractor's self-confirmation. If the controlled type is defined, any supervisory tasks should not be mitigated. All tasks should be executed under the client's control.

After the surveillance types are defined, the 90 supervisory tasks are classified into two groups. One is the task group that the clients should control, and another is the group that the contractors should execute by their self. The process of using the chart is mentioned later.

3.1.3 Outcomes and total consideration

The final outcomes of figure2 are as follows.

(1) Outcome1: Definition of surveillance types

(2) Outcome2: Structure of supervisory tasks

To obtain these outcomes, it is important to make adequate consideration with total interpretation shown in the flow chart. The total interpretation is sensitive and crucial process in that the contractor's potential such as a basis of inspection, a feedback system of past-occurred problem, and a capability of contractor's superintendent have to be considered. Consideration of these elements depends on the experience of client's supervisory personnel.

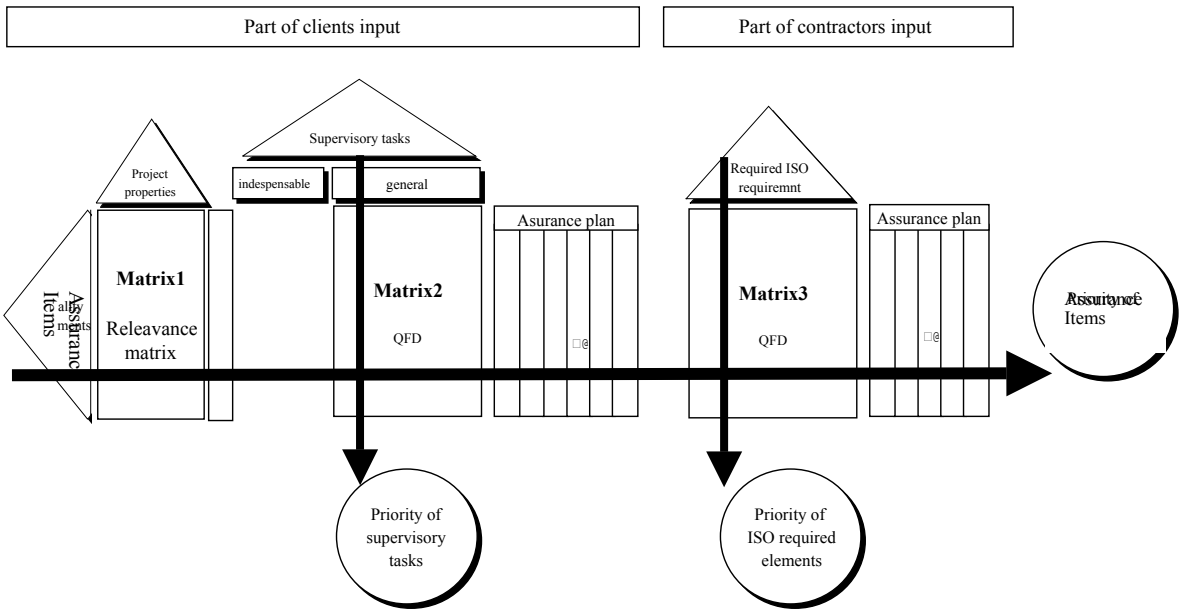

Figure3. Priorities obtained from quality function development drawing

The outcomes of the upper side can be obtained automatically because a computer-aided tool can calculate the priorities. On the contrary, the outcomes of the lower side are derived form empirical consideration. The mixture of the automatic calculation and the empirical consideration are intended form the beginning of developing R-QFD.

3.2 Procedure of R-QFD

Procedure of R-QFD is as mentioned below. Detail contents of matrixes and tables are mentioned also.

3.2.1 Procedure1: matrix1

Matrix1 consists of 18 assurance items and 10 project properties. As far as QFD matrix concerns, intensity levels of relation should be input-data. Evaluation is not the scope of QFD matrix. In the matrix1, Relevance Matrix that is one of the evaluation methods is applied so that the project properties can evaluate the assurance items. The clients make the evaluation and evaluation range is form 0 that means no importance to 4 that means extremely important. The content of matrix1 is as shown in figure 4. The data indicated in the matrix were given in the experimental project mentioned later.

3.2.2 Procedure2: matrix2

Matrix2 is a QFD matrix that consists of 18 assurance items and 90 supervisory tasks. The clients give the level of relation between each item and task into the matrix2. There are three levels of the relation. Level1 means a little relation. Level2 means a fair relation. Level3 means very close relation. The part of content of matrix2 is as shown in figure 5. The data indicated in the matrix were given in the experimental project mentioned later.

3.2.3 Procedure3: client's assurance plan

As mentioned already, assurance plan is a new idea introduced in this paper. The contents of client's assurance plan are as follows.

(1) Client's assurance plan is the idea developed by modifying quality plan of QFD.

(2) Client's assurance plan expresses the clients' expectation level in assuring quality.

(3) The expectation level is influenced intensively by level-up ratio.

			Project properties										
			1	2	3	4	5	6	7	8	9	10	
		Evaluation ranks 4 ..extremely important 3 ..fairly important 2 ..relatively important 1 ..a little bit important 0 ..not important at all	Scale and structure	Project schedule	Technical property	Design change	external environment	Legitimacy	Safety	Neighborhood	Progress of work	Superintendent ability	Weights of quality elements based on the project properties
		Weight of evaluation(1 9)	5	9	5	3	3	5	3	7	3	5	(X)
Quality element	1	Safety for structure	1	3	2	0	1	1	0	0	1	1	**7.1**
	2	Safety for fire	1	1	2	0	0	1	0	0	1	1	**4.3**
	3	Safety for accident	1	2	2	0	3	1	0	0	1	1	**6.7**
	4	Changeability for remodeling	1	1	1	0	0	1	0	0	0	1	**3.6**
	5	Flexibility for IT	1	3	1	0	0	1	0	0	0	1	**5.9**
	6	Accessibility	0	0	1	0	1	0	0	0	0	1	**1.4**
	7	Suitability	1	2	1	0	1	1	0	0	0	1	**5.1**
	8	Security system	1	2	1	0	0	1	0	0	0	1	**4.7**
	9	Comfortability	1	1	1	0	3	1	0	0	0	1	**4.7**
	10	Durability	1	1	2	0	3	1	0	0	0	1	**5.1**
	11	Maintainability	2	1	3	0	2	1	0	0	0	1	**5.8**
	12	Communication	1	1	1	0	0	0	0	0	0	1	**2.9**
	13	Landscape management	1	1	1	0	0	0	0	1	0	1	**3.8**
	14	Environment conservation	1	4	1	1	0	1	0	0	0	1	**7.1**
	15	Administration of contract	1	1	1	2	1	1	3	1	2	3	**8.2**
	16	Compensation of requirement to post office	2	2	1	2	1	0	1	1	1	2	**7.5**
	17	Compensation of neighborhood nuisance	1	0	1	0	1	0	3	4	0	2	**7.6**
	18	Safty and schedule of construction site	1	1	1	1	1	0	4	2	4	1	**8.3**

Figure4. Contents of matrix1 (part)

The level-up ratio is calculated by the following equation.

Level-up ratio (Z) = weight B / weight A

Weight A is an actual weight given by the clients at present condition.
Weight B is an expectation weight driven by considering others' weights.
*If B is lower than A, ratio Z becomes level-down ratio.

(4) The out-put of assurance plan is the assurance plan weight.
(5) The assurance plan weight is calculated by the following equation.

Assurance plan weight = weight X * weigh Y * weigh Z

Weight X is a weight obtained from matrix1.
Weight Y is a weight given by users of buildings, who are the end-customers of projects' clients
Weight Z is level-up ratio mentioned above.

The part of the content of the client's assurance plan is as shown in figure 6. The data indicated in the matrix were given in the experimental project mentioned later.

3.2.4 Procedure4: matrix3

Matrix 3 is a QFD matrix that consists of 18 assurance items and 59 ISO required items. The contractors give a level of relation between items into the matrix3. There are three levels of the relation. The meaning of each level is same as matrix 2. The part of content of matrix3 is as shown in figure 7. The data indicated in the matrix were given in the experimental project mentioned later.

Assurance items \ Supervisory tasks	1 Confirmation of scheme of execution	2 Approval of scheme of execution work	3 Approval of scheme of fundation and piling work	4 Approval of scheme of shoring work	5 Approval of scheme of reinforced concete work	6 Approval of scheme of formwork	7 Approval of scheme of steel reinforcement work	8 Approval of scheme of fabricating of structural steel	9 Approval of scheme of structural steel work	10 Approval of scheme of concrete block work	11 Approval of scheme of waterproofing work	12 Approval of scheme of stone masonry work	13 Approval of scheme of tile work	14 Approval of scheme of roofing work	15 Approval of scheme of metal work	16 Approval of scheme of plaster work	17 Approval of scheme of doors and windows work	18 Approval of scheme of painting work	19 Approval of scheme of interior finishing work	20 Approval of scheme of pavement work
□ @&@.....very close relation																				
□ @&@.....fairly close relation																				
□ @&@.....a little relation																				
1 Safety for structure		5	5	1	5	3	5	5	5	1										
2 Safety for fire										3					1		5		5	
3 Safety for accident												5	5							3
4 Changeability for remodeling					1					3					1	1			1	
5 Flexibility for IT																			1	
6 Accessibility																				
7 Suitability											5	3		3	3	3	3	3	3	
8 Security system																	5			
9 Comfortability																				
10 Durability		1	3		5	5	5	5	3		5	5	5	5	3	5	3	3	3	3
11 Maintainability											5	5	5	3	3	3	3	3	3	3
12 Communication																				
13 Landscape management																				
14 Environment conservation		5	5	5	1	5														5
15 Administration of contract																				
16 Compensation of requirement to post office																				
17 Compensation of neighborhood nuisance	3	1	1	3	1	1			1		1					1				1
18 Safty and schedule of construction site	5	3	3	5					3											

Figure 5. Contents of matrix2 (part)

			Assurance plan											
					Comparative			Plan		Weight				
		□ @@P..Not expect at all □ @@Q.Not expect so much □ @@R.Expect a little bit □ @@S..Expect fairly □ @@T..Expect strongly	Weight of quality elements based on project properties (X)	Weight of end user needs (Y)	Weight of section of building management	Weight of section of project administration (A) PM	Weight of section of building services	Weight of expectation considering other's weight (B)	Level-up ratio (Z=B/A)	Weigh 1(X*Y)	Weigh 2(% of X*Y)	Weigh 3(X*Y*Z)	Weight of assurance plan (% of X*Y*Z)
Quality elements	1	Safety for structure	7.1	1	1	1	1	1	1.0	7.1	7.1	7.1	6.9
	2	Safety for fire	4.3	1	1	1	1	1	1.0	4.3	4.3	4.3	4.2
	3	Safety for accident	6.7	1	1	1	1	1	1.0	6.7	6.7	6.7	6.5
	4	Changeability for remodeling	3.6	1	1	1	1	1	1.0	3.6	3.6	3.6	3.5
	5	Flexibility for IT	5.9	1	1	1	2	1	1.0	5.9	5.9	5.9	5.8
	6	Accessibility	1.4	1	1	1	1	1	1.0	1.4	1.4	1.4	1.4
	7	Suitability	5.1	1	1	1	2	1	1.0	5.1	5.1	5.1	5.0
	8	Security system	4.7	1	1	1	1	1	1.0	4.7	4.7	4.7	4.6
	9	Comfortability	4.7	1	1	1	3	1	1.0	4.7	4.7	4.7	4.6
	10	Durability	5.1	1	1	1	1	1	1.0	5.1	5.1	5.1	5.0
	11	Maintainability	5.8	1	3	1	1	1	1.0	5.8	5.8	5.8	5.6
	12	Communication	2.9	1	1	1	1	1	1.0	2.9	2.9	2.9	2.8
	13	Landscape management	3.8	1	1	1	1	1	1.0	3.8	3.8	3.8	3.7
	14	Environment conservation	7.1	1	1	1	1	1	1.0	7.1	7.1	7.1	6.9
	15	Administration of contract	8.2	1	5	1	1	2	2.0	8.2	8.2	16.3	15.9
	16	Compensation of requirement to post office	7.5	1	3	1	1	1	1.0	7.5	7.5	7.5	7.3
	17	Compensation of neighborhood nuisance	7.6	1	1	1	1	1	1.0	7.6	7.6	7.6	7.4
	18	Safty and schedule of construction site	8.3	1	1	3	1	1	0.3	8.3	8.3	2.8	2.7

Figure 6. Contents of table1

	ISO required elements	4.1					4.2			4.3			
		Management responsibility					Quality system			Contract review			
		4.1.1	4.1.2			4.1.3	4.2.1	4.2.2	4.2.3	4.3.1	4.3.2	4.3.3	4.3.4
Assurance items	□ @¥ £ ¤ –¨ É ‰º Ì Ž § ð ¤ –Í □ @&@.....very close relation □ @&@.....fairly close relation □ @&@.....a little relation	Quality policy	Organization 1.0 Responsibility and authority	2.0 Resources	3.0 Management representative	Management review	General	Quality system procedure	Quality planning	General	Review	Amendment to a contract	Records
1	Safety for structure	0.7	0.7	0.7	0.7	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.7
2	Safety for fire	0.7	0.7	0.4	0.4	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
3	Safety for accident	0.7	0.7	0.7	0.7	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.0
4	Changeability for remodeling	0.0	0.0	0.4	0.0	0.0	0.4	0.4	0.4	0.0	0.1	0.0	0.0
5	Flexibility for IT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0
6	Accessibility	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0
7	Suitability	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0
8	Security system	0.0	0.7	0.4	0.7	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
9	Comfortability	0.4	0.7	0.7	0.7	0.0	0.0	0.0	0.0	0.0	0.9	0.1	0.0
10	Durability	0.0	0.4	0.4	0.4	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.7
11	Maintainability	0.0	0.7	0.7	0.7	0.0	0.4	0.4	0.4	0.0	0.9	0.4	0.0
12	Communication	0.0	0.4	0.4	0.4	0.0	0.4	0.4	0.4	0.0	1.1	0.7	0.0
13	Landscape management	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.7	0.0
14	Environment conservation	0.0	0.7	0.7	0.7	0.0	0.0	0.0	0.0	0.0	0.4	0.7	0.0
15	Administration of contract	1.4	1.1	1.4	1.4	0.7	0.0	0.0	0.0	0.1	3.6	4.0	2.4
16	Compensation of requirement to post office	0.4	0.7	0.7	0.7	0.0	0.0	0.0	0.0	0.1	2.3	2.0	1.0
17	Compensation of neighborhood nuisance	0.9	1.1	1.1	1.4	0.7	0.0	0.0	0.0	0.0	0.4	0.0	0.4
18	Safety and schedule of construction site	1.4	1.4	1.1	1.4	0.7	0.0	0.0	0.1	0.0	0.7	0.9	0.7

Figure 7. Contents of matrix3 (part)

MPT's assuarance weight

Assurance items #		
15	Administration of contract	15.9
17	Compensation of neighborhood nuisance	7.4
16	Compensation of requirement to post office	7.3
1	Safety for structure	6.9
14	Environment conservation	6.9
3	Safety for accident	6.5
5	Flexibility for IT	5.8
11	Maintainability	5.6
7	Suitability	5.0
10	Durability	5.0
8	Security system	4.6
9	Comfortability	4.6
2	Safety for fire	4.2
13	Landscape management	3.7
4	Changeability for remodeling	3.5
12	Communication	2.8
18	Safty and schedule of construction site	2.7
6	Accessibility	1.4

Contractor's assurance weight

Assurance items #		
18	Safty and schedule of construction site	8.2
15	Administration of contract	8.1
16	Compensation of requirement to post office	8.0
17	Compensation of neighborhood nuisance	7.5
1	Safety for structure	7.0
14	Environment conservation	7.0
3	Safety for accident	6.6
11	Maintainability	5.9
5	Flexibility for IT	5.8
7	Suitability	5.1
10	Durability	5.1
8	Security system	4.8
9	Comfortability	4.7
2	Safety for fire	4.3
13	Landscape management	3.8
4	Changeability for remodeling	3.6
12	Communication	3.1
6	Accessibility	1.4

Table 1. Comparison of MPT's and contractor's assurance weight

3.2.5 Procedure5: ISO contractor's assurance plan

The concept of ISO contractor's assurance plan is same as the client's assurance plan. Contractor's assurance plan expresses the contractor's intention level in assuring quality.

3.2.6 Procedure6: Total interpretation

In the total interpretation, three aspects mentioned below are considered at the same time.

(1) Aspect1: comparative analysis

Client's assurance plan weight and contractor's assurance plan weight are compared. The differences between the level of client's expectation and that of contractor's intention in each assurance item are examined through the comparative analysis.

(2) Aspect2: priorities

Both the priority of supervisory tasks calculated by matrix2 and the priority of ISO required items calculated by matrex3 are examined

(3) Aspect3: contractor's potential

The contractor's elements such as a basis of inspection, a feedback system of past-occurred problem, and a capability of contractor's superintendent are considered. The surveillance type and the structure of supervisory tasks are defined through the consideration mentioned above.

4. EXPERIMENT

R-QFD was applied to a real building construction project in order to verify the problem and the validity of R-QFD. The client is MPT and the building is a newly built post office. The total area is 23,290m^2 and the structure is RC-4stories.

Two superintendent personnel of MPT and seven contractors' stuffs including superintendent input their expectation and intention into the R-QFD questionnaire. The questionnaire covers the upper side of figure2.

5. ANALYSIS

The R-QFD questionnaires were analyzed as well as the total interpretation was executed. The results of the analysis and interpretation are as mentioned below.

5.1 Comparative analysis

The client's and the contractor's assurance plan weights are shown in table 1. As observed in the table, the order of the weights is extraordinary identical. The remarkable difference is observed at the assurance item "safety and schedule of construction site", which

is to assure the security of the construction site and to keep the time for completion. That item ranks second last for MPT, and top for the contractors. This happens because MPT gave 0.3 as the level-up ratio (0.3 means level down) on this item. MPT thought that the obligation of the task for safety and schedule of construction site could be left to the contractor, because the contractor is ISO9000s certified. Even more, the contractor ranks the item top. It is, therefore, natural for MPT to recognize that the supervisory tasks regarding to safety and schedule of construction site can be mitigated.

5.2 Priority of supervisory tasks

The priority of supervisory tasks is shown in table 2. Top three tasks are all about confirmation on the completed matter or the results of site jobs. These tasks are insensibly important for MPT and should not be mitigated.

Check between contract documents and construction work	358.2
Check between contract documents and shop drawings	358.2
Attention to bad performance	342.7
Approval of construction planning	309.1
Confirmation of progress photographs	289.4
Coordination among several contracts	202.3
Confirmation of subcontractors	171.0
Direction of making manualbook of how to use	161.3
Explanation of how to use	161.3
Confirmation of out of quality standard	145.4
Confirmation of monthly reports	122.2
Confirmation of monthly programs	121.8
Advise to compensation of neighborhood nuisance	116.7
Advice to regal reports to government	113.7
Approval of schedule of shop drawings	107.2
Approval of management schedule	105.0
Confirmation of site management organization	104.9
Approval of scheme of masonry work	100.9
Advice to construction management	99.9

Table 2. Priority of supervisory tasks

4.10 Inspection and testing	4.10.2	Receiving inspection and testing	3 Emergency conpensation for nonconforming	66.4
4.10 Inspection and testing	4.10.3	In-process inspection and testing		64.4
4.10 Inspection and testing	4.10.4	Final inspection and testing		63.6
4.9 Process contraol				63.4
4.10 Inspection and testing	4.10.2	Receiving inspection and testing	1 Clarification of receiving	63.3
4.10 Inspection and testing	4.10.5	Inspection and test records		60.5
4.6 Purchasing	4.6.4	Verification of purchased product	2 Customer vertification of subcontracted product	53.7
4.8 Product indentification and traceability				44.1
4.17 Internal quality audits				41.5
4.5 Document and data control	4.5.2	Document and data approval and issue		39.2
4.10 Inspection and testing	4.10.2	Receiving inspection and testing	2 Record of conformity of subcontracted control	38.9
4.5 Document and data control	4.5.3	Document and deta change		36.9
4.16 Control of quality records				35.8
4.6 Purchasing	4.6.4	Vertification of purchased product	1 Supplier vertification at subcontractor's premises	31.8
4.13 Contorl of nonconforming product	4.13.2	Review and dispositon of nonconforming		24.8
4.6 Purchasing	4.6.3	Purchasing data		23.0
4.12 Inspection and status				21.7
4.11 Control of inspection, measuring and test equipment	4.11.2	Control procedure		21.6
4.19 Servicing				19.9

Table 3. Priority of required ISO elements

5.3 Priority of required ISO elements

The priority of required ISO elements is shown in table 3. Top six elements are all about inspections and examinations. This means that the contractor regards the inspection and examination as the most important task for assuring the quality of the project. If the contractor's basis of inspection is appropriate, it is possible for MPT to mitigate supervisory tasks regarding inspection and examination. Mitigation of the supervisory tasks in inspection means that the presence of MPT supervisory personnel at the site is not necessary. MPT personnel may be able to observe the inspection results only by checking the contractor's ISO documents.

5.4 Total interpretation and surveillance type

MPT Supervisory personnel investigated the ability of the contractor in terms of the basis of inspection, a feedback system of past-occurred problem, and a capability of contractor's superintendent. The basis of inspection of the contractor was checked by their quality standards defined in the ISO9000s quality plan, and the basis was recognized as reliable. The feedback system of the past-occurred problem was not confirmed, but the contractor was recognized as a reliable constructor because the past accomplishments of the contractor in the same type of project procured by MPT ranks relatively high. The capability of contractor's superintendent was considered as excellent through his past achievements and direct interview.

In conclusion, it is decided to apply point-focused type as the surveillance type. The mitigation of supervisory tasks regarding to safety and schedule of construction site was applied. In this mitigation, the supervisory tasks especially in inspection and examination considered. The numbers of mitigated tasks are as shown in table4. As a whole, the rate of mitigation reached up to 39% out of all tasks described in specification.

6. CONCLUSIONS

Because the project is still under construction, the justification of R-QDF is still being examined. The following two points are the effectiveness of R-QFD observed by MPT at this moment.

6.1 Promotion of understanding by numerical values.

The outcomes of the upper side of figure2 are given by numerical values. In general, it is extremely difficult to make clear priority among many items, and it is highly possible to have the conclusion that every item is important. The clear priority given by the R-QFD is

Table 4. Actual contents of mitigation of supervisory tasks

<table>
<tr><th>Contens of Supervisory tasks</th><th>Number of tasks</th><th>Number of mitigated tasks</th><th>Mitigated rate</th></tr>
<tr><td>Confirmation at the site</td><td>4</td><td>2</td><td rowspan="4">47%</td></tr>
<tr><td>Inspection and comfirmation</td><td>106</td><td>46</td></tr>
<tr><td>Approval shop drawing</td><td>87</td><td>38</td></tr>
<tr><td>Approval of scheme of execution</td><td>22</td><td>18</td></tr>
<tr><td>Adustment of another project</td><td rowspan="4">45</td><td rowspan="4">0</td><td rowspan="4">Indispensable tasks for supervisory personnel</td></tr>
<tr><td>Compensation of neighborhood</td></tr>
<tr><td>Design change</td></tr>
<tr><td>Administration of contract</td></tr>
<tr><td>Total</td><td>264</td><td>149</td><td>39%</td></tr>
</table>

though to be effective for the client's decision making.

Knowing the priority of the assurance items is effective not only for the clients, but also for the contractors, because the contractors can make clear strategy for the clients' satisfaction. It is effective to have numerical values for both the clients and the contractors.

6.2 Clarification of the discussion

Assurance plan, which is newly developed concept, contributed to make the discussion objectives clear. In this trial project, the discussion objective was the remarkable difference observed at the item "safety and schedule of construction site. The level-up ratio of that item was discussed between MPT and the contractor. It was effective to inform the contractor that MPT expected to mitigate the supervisory tasks regarding to that item.

7. FUTURE DEVELOPMENTS

The numerical values of the upper side of figure2 were calculated by spreadsheet type computer software (Excel 2000). It is easy to operate the spreadsheet on web basis and both clients and the contractors can input their expectation and intension through online. The analysis of these data can be used for the communication between clients and contractors form pre-contract phase.

If the contractors establish the project database and supply data about the past-occurred problems as the digital contents, it is possible to develop the problem feed back system. By combining R-QFD and the feed back system, it may be able to establish the knowledge management system for quality control.

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