COST MANAGEMENT USING 3D MODELING

- DESIGN AND PRODUCTION PROCESS IN VIEW OF THE CLIENT SATISFACTION -

Hiromitsu SONE
Building Department
Maeda Corporation
Tokyo Chiyoda Fujimi 2-10-26
sone.h@jcity.maeda.co.jp

Makoto NAGAO
Building Division
Maeda Corporation
Tokyo Chiyoda Fujimi 2-10-26

Hirohiko FUJII
Building Engineering & Design Department
Maeda Corporation
Tokyo Nerima Takamatsu 5-8 J-City

Abstract: With the decline of construction investment, client's demand for "Quality" "Cost Down" and "Shorter Construction Period" becomes more intense. And some surveys show that most dissatisfied contractor's service for client goes to cost related matter including cost management and unclear decision making process. This report tries to demonstrate how one of the most advanced information technologies, "3D Modeling" can help to clarify cost management and decision making process. Also it helps to share the project related information among project members including the client and it eventually leads to more effective cost management.

Keywords: Design by 3D Model, Client Satisfaction, Cost Management, Integrated Design

1. THE BACKGROUND AND OBJECTIVE OF THIS RESEARCH

With the decline of construction investment, client's demand for "Quality" "Cost Down" and "Shorter Construction Period" becomes more intense. Under the circumstances, we set our goal to achieve the maximum production efficiency by integrating design data from "Planning", "Schematic Design", "Detailed Design", and "Estimation" through "Construction" using 3D model.

In a building industry, we saw a rapid development of 2D CAD since late 1980s, and we achieved tremendous reduction of drafting time by replacing pencil with mouse and keyboard. On the other hand, 3D modeling was also developed since late 1980s. However, visual effect was emphasized such as Computer Graphics (CG). Although many 3D modeling software was developed in the late 1990s, it is hard to say that it was widely spread due to difficulty of software handling.

In terms of Corporate Social Responsibility, in construction industry we find various aspect of demand from clients especially after the personnel's camouflage of structural design data scandal occurred in 2005. In order to respond such demands, producers (designer and contractor) are required to demonstrate legitimacy for quality and cost of products. From clients' point of view, the process from design through construction is not transparent enough, and it leads to distrust between client and designer/contractor. In this paper, we demonstrate effectiveness of 3D modeling for design/production system through clarifying elements of service we provide and its cost.

2. CURRENT SITUATION OF CONSTRUCTION PROCESS AND ITS PROBLEMS

2.1 Client's Dissatisfaction

In order to complete a project, stakeholders including client, designer, contractor, end-user, and investor interact each other in respective phase of the project. With a change of the surrounding environment for client and contractor, we see more opportunity for a client to interact with project, and accordingly we see more demand from them. According to the survey for client satisfaction conducted by The Japan Institute of Architects [1], the most dissatisfied architectural works include the problems about "Maintenance Program" "Cost Control" "Project Budgeting" "Follow-up after Completion" "Estimation Review" and "Rough Estimation of Construction Cost". And actual demand from the client includes "Cost Reduction" and "Transparency of Costing and Decision Making Process". As for the contract scheme, a lump sum contracting in which a construction company takes a role of general contracting is viewed as good scheme in terms of cost control capability, however it is also viewed negatively in terms of transparency [2]. In summary, it is said that a client is most sensitive to cost.

2.2 Problems for Designer and Contractor

Currently a client has only two opportunities to grasp the construction cost; namely at rough estimate after completion of schematic design, and at detailed estimate after completion of detailed design. So it is hard to acknowledge construction cost accurately until completing detailed design document. We see more cases these days that a contract is made only with preliminary drawing and rough estimate. And in these cases, design work and communication with the client are progressed from rough stage to detailed stage without knowing whether the construction cost is within the budget or not. Therefore, if the client finds that the construction cost is over the budget only after completion of the detailed design, the detailed drawings must be adjusted. Design and cost adjustment at this phase, however, is very time consuming and inefficient. Also mismanagement at design phase leads to inefficient work at latter phase (construction) including (1) design review by "Value Engineering" and "Specification

Down" (2) settlement of unsolved problem at design phase (3) adjustment of design inconsistency tending to cause more work (Figure-1). Also as Japan's unique business practice, a client tends to regard that any indefinite scope of work goes to contractor's responsibility without cost increase, and it creates ambiguity of responsibility between the client and the contractor. In many cases, detail is not fixed at design phase, and it causes misunderstanding in which client/designer think it as design alteration while contractor thinks it as additional work. Difficulty to visualize completed building image and concrete way of use of the building for the client is one of the major reasons not to be able to fix the details at design phase. Therefore, to fix an "un-fixed item" at the design phase is just a fixing on drawings and it is not necessarily in line with what client and contractor have in their mind. These ambiguities that Japan traditionally has must be clarified by increasing the amount of information given to the client. Also it is very important to make every project members including client understand that design changes come with cost (including man hours).

3. THE BACKGROUND OF INTRODUCING 3D MODELING

3.1 The History of 3D Modeling in Our Company

The first instance we used 3D modeling was project of a commercial complex of which the construction started in July 2000. Although we started using 3D modeling from the construction stage of the project, we made sure that 3D modeling was very useful particularly in case of curved surfaces. After the good result we got, we tried next 3D modeling on a project of a distribution facility in 2001 with the members of design and construction sides. The objective was to respond to the client's demands for checking the distribution lines on 3D model. We realized the advantages of 3D modeling in case of making the client visualize the system and in checking the integration of the lines with the structure. However the elements of the building have been all modeled at the detail of construction level which frequently posed problems on the operation of the computers. So we decided to check out our process of modeling and improve the software we used. In 2003 we were able to use again 3D modeling in the projects of high rise residential buildings with the new methods we introduced. Currently, we are using 3D modeling also in the projects such as industrial factories, warehouses, laboratory facilities and retail stores.

3.2 The Purpose of Using 3D Modeling

In order to organize the client's demands and to have an effective production process from design through construction, it is necessary to correspond to the process starting from the early stages. We thought that it was also important to make the decision making process clear taking the client's opinions into consideration and tried to introduce a system which also allowed the designer and the constructor to control the cost timely. The system consisted of the following five items:

(1) Design with visual simulation and communication (Improving the proposal skills and fastening the decision making process).
(2) Timely cost management (Controlling the quantities through various attributes of the models)
(3) Improving the quality by consistent drawings.
(4) Schedule management using the same model data from design through construction.
(5) Using the data in the construction stage for various items such as planning of the temporary work, shop drawings, drawings of pre-cast concrete (PCa) members and steel members for the manufacturers.

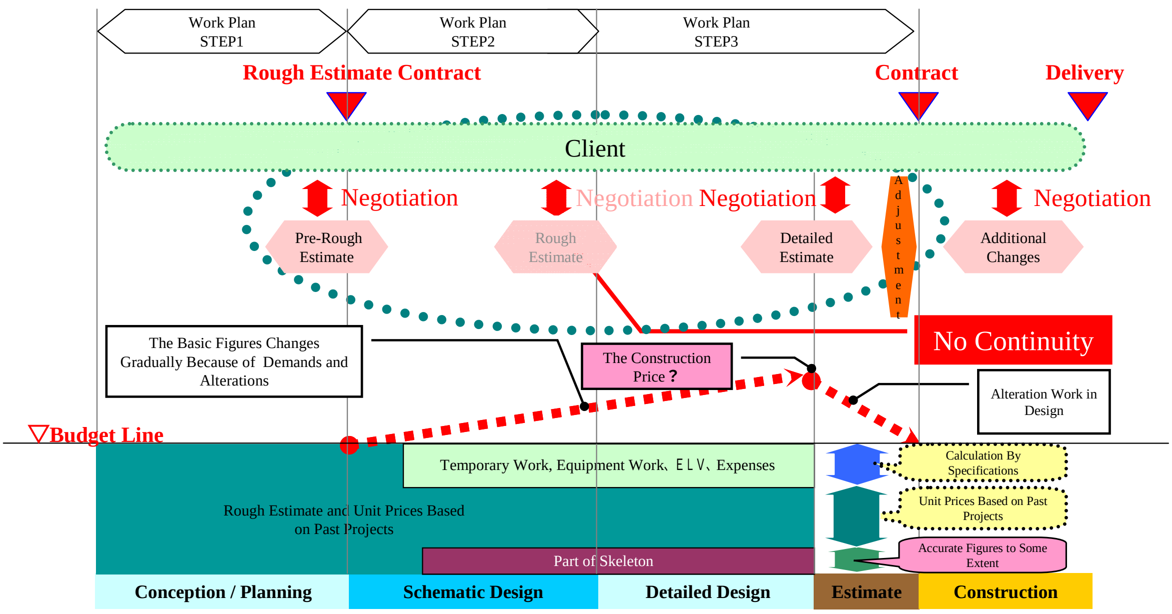

Figure-1 Conventional Work Flow

In the following paragraphs, three examples of buildings different in use and structure are introduced which had satisfactory results in cost management combining the items mainly (1) and (2) mentioned.

4. EXAMPLES OF COST MANAGEMENT

4.1 The Process Using 3D Modeling

In order to grasp the cost, it is important to reflect the demands of the client to the project and establish a connection with the cost management starting from the early stages. At this point we introduced a process based on the following procedures:

(1) Quantifying the elements in the model by the attributes attached to the models. Grasping the cost by checking out the 3D calculated quantities frequently helps to explain the client the deviation if any from the budget and minimize the possible gap in the end (Figure-2).

(2) Showing the entire building including exterior and interior on 3D model. This helps to have all members involved in the project including the client to have a common image of what is being planned. By this way we are able to understand the demands of the client and the decision process becomes clearer (Figure-3). In order for a client to view the building, computer graphics (CG) has been a tool to be used commonly. The advantage of visualizing the building on 3D model compared to CG is that it is possible to check the architectural information such as dimensions and the attributes of the elements. By this way it becomes possible to have an idea about the architecture, structure and equipment integration necessary for a total design including the issues of getting rid of unnecessary spaces and deciding on spaces reflecting the compactness and the use of the building effectively. It is said that 80% of the total cost of a project becomes clear before 20 % of the whole project is over. So it is important to make early decisions based on the demands of the client.

Figure-3 3D Meeting with the Client

Combining the two above-mentioned items, it became possible to control the cost based on the 3D image by holding meetings with the client frequently which was not possible before unless the drawings were complete.

4.2 3D Calculated Quantities

In order to control the attributes, it is necessary to cut down the time and minimize human error during modeling. The effectiveness in controlling the attribute is one of the most important points of using 3D modeling. In order to make this possible, we improved the software we were using by introducing programs. The programs made it possible to control the attributes of the elements such as the partition types, the specifications about the boards, finish etc. on a spreadsheet making it easy to control the 3D calculated quantities (Figure-4).

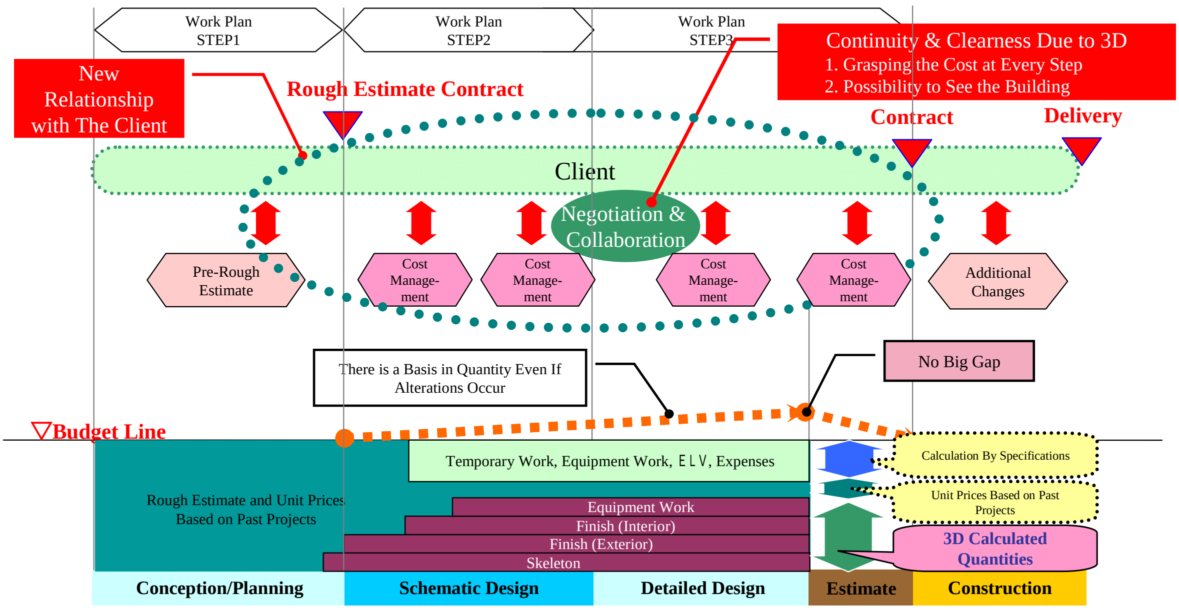

Figure-2 New Work Flow

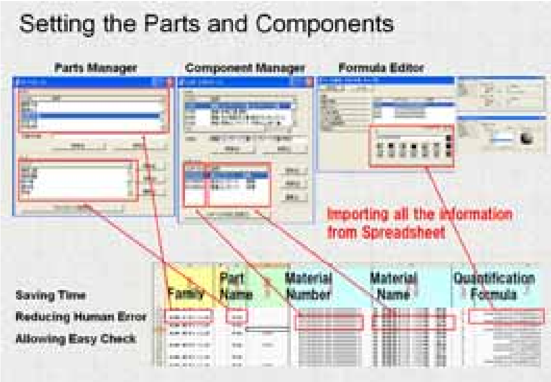

Figure-4 Controlling the Attributes by Spreadsheet

Although the output quantities don't give all of the figures necessary for the detailed estimation, they give enough idea to grasp the cost due to the steps of the design process when the following items are applied.

(1) Aiming at mainly the quantities of skeleton work, finish (interior, exterior) work and equipment work. The other costs are not aimed at such as earth work, pile work, earth retaining wall work, or the ones which are not directly calculated from the design documents such as temporary work, machinery, site equipments, and various expenses.

(2) In each work, concentrating on the elements which have a high percentage of the total cost. And these elements may change according to the use of the building.

After taking out the 3D calculated quantities, we arrange them on a spreadsheet (Table-1) and calculate the cost by multiplying the figures by unit prices.

Table-1 Part of a Quantification Spreadsheet

Dwelling	Room	Element	Finish	Sunbstrate	Quantity	Unit
A Type	Entrance	Wall	Vinyl Covering	Fireproof Sound Insulation Partition	18.68	m2
			Vinyl Covering	Waterproof Board t12.5	45.45	m2
		Baseboard	Wooden Baseboard	H=60 Vinyl Chloride Sheet	24.2	m
		Column	Vinyl Covering	Gypsum Board t12.5 GL Moldproof Foamed Urethane t25 RC	2.99	m2
	Corridor	Wall	Vinyl Covering	Fireproof Sound Insulation Partition	18.68	m2
			Vinyl Covering	Fireproof Board t12.5 Wooden Frame	45.45	m2
		Baseboard	Wooden Baseboard	H=60 Vinyl Chloride Sheet	24.2	m
		Column	Vinyl Covering	Gypsum Board t12.5 GL Moldproof Foamed Urethane t25 RC	2.99	m2
	Western Style	Wall	Vinyl Covering	Waterproof Board t12.5 Wooden Frame	64.13	m2
		Baseboard	Soft Baseboard	H=60	24.2	m
		Column	Vinyl Covering	Gypsum Board t12.5 GL Moldproof Foamed Urethane t25 RC	2.99	m2
	Japanese Style	Wall	Vinyl Covering	Gypsum Board t12.5 Wooden Frame	64.13	m2
		Baseboard	Soft Baseboard	H=60	24.2	m
		Column	Vinyl Covering	Gypsum Board t12.5 GL Moldproof Foamed Urethane t25 RC	2.99	m2
	Kitchen	Wall	Vinyl Covering	Gypsum Board t12.5 GL Moldproof Foamed Urethane t25 ALC	64.32	m2
		Baseboard	Soft Baseboard	H=60	25.25	m
		Column	Vinyl Covering	Gypsum Board t12.5 GL Moldproof Foamed Urethane t25 RC	2.99	m2
	Unit Bathroom	Wall	Vinyl Covering	Gypsum Board t12.5 Wooden Frame	64.32	m2
		Baseboard	Soft Baseboard	H=60	24.27	m
		Column	Vinyl Covering	Gypsum Board t12.5 GL Moldproof Foamed Urethane t25 RC	2.99	m2
B Type	Entrance	Wall	Vinyl Covering	Fireproof Sound Insulation Partition	18.68	m2
			Vinyl Covering	Gypsum Board t12.5 Sound Insulation Partition	45.45	m2
		Baseboard	Wooden Baseboard	H=60 Vinyl Chloride Sheet	24.2	m
		Column	Vinyl Covering	Gypsum Board t12.5 GL Moldproof Foamed Urethane t25 RC	2.99	m2
	Corridor	Wall	Vinyl Covering	Fireproof Sound Insulation Partition	18.68	m2

4.3 Grasping the Cost According to the Use of Buildings

The points we took into consideration, the 3D calculated quantities and the ratios of the grasped cost of the three buildings (All design and build) are explained in the following paragraphs (Table-2).

Table-2 Outline of the Three Buildings

Building Use	Residential Building	Laboratory Facility	Industrial Factory
Structure	RC	RC (Partly S)	S
No of Floors	B.1 F.33 PH.2	B.0 F.7 PH.1	B.0 F.1 PH.0
Total Area (m^2)	30,260.1	12,800.0	5,669.0
Height (m)	106.3	35	11.4

4.3.1 High Rise Residential Building [3]

For the skeleton, through the design process we took out the 3D calculated quantities of the PCa members which had a high cost percentage. For the concrete, we checked the volume by parts. For the reinforcing bars, we checked the weight by specifications at the schematic design and additionally the cutting lengths of the bars and the welding points of the bars at the detailed design. For the exterior finish work, besides performing a simulation by 3D model for the client, we performed also a cost simulation by checking out the quantities of the materials in case of an alteration. For the interior finish work, in case of residential buildings actually it is easy to grasp the cost using the values of the past projects and there is not much need of 3D modeling for all of the details. However as our purpose was using the 3D model not only for cost management but also for checking the integration of the elements in the following stages, we aimed at calculating the areas of the rooms according to the types of the dwellings. The reason we aimed at the types of the dwellings was that the areas of the rooms were same for each type and there was the possibility of personnel changes for each dwelling after the start of the construction. For the equipment works, at the schematic design we concentrated on the route of the air ducts which had a high cost percentage. At the detailed design stage we arranged the location of the equipment joints and PCa member sleeves also calculating the accurate quantities which we were calculating by using unit prices for the equipments before. The ratios of the 3D calculated quantities are shown in Figure 5. ①+②is the part aimed to be calculated by 3D which is 61.0%of the whole budget (①+②+③). ① is the 3D calculated part which is 46.6% of the whole budget. So 78.6% of the aimed part was calculated by 3D.

4.3.2 Laboratory Facility [4]

Basically the procedure was same with the residential building. However, since the level in requirements for the building as a laboratory differed with the residential building, using average values for quantifying might have resulted in underestimation. Because of this, we introduced some treatments such as rough modeling and quantification at schematic design (Figure-8), combined modeling of equipments with architectural and structural members, and using modules in order to correspond to the changes quickly. The ratios of the 3D calculated quantities are shown in Figure 6. ①+②is the part aimed to be calculated by 3D which is 44.2%of the whole budget(①+②+③). ① is the 3D calculated part which is 40.7% of the whole budget. So 92.1% of the aimed part was calculated by 3D.

4.3.3 Industrial Factory

As in the laboratory facility, we used rough models in order to grasp the 3D calculated quantities starting from the planning stage. Since the factory included coating lines which required special treatment concerning air tightness, we checked the locations of the lines and their relationship to surrounding members on 3D model throughout the design process. As the building was a steel structure, the cost of the steel members occupied 15~18% of the whole cost. So we focused on the detail modeling and quantification of the steel members from the planning stage through ordering the members and construction stages. The costs of the exterior parts were calculated by just quantifying areas since the members were same through the area. The costs of the interior parts were calculated in accordance with each room, also with the ceilings, the walls and the floorings for each room. The ratios of the 3D calculated quantities are shown in Figure 7. ①+②is the part aimed to be calculated by 3D which is 56.7%of the whole budget(①+②+③). ① is the 3D calculated part which is 47.3% of the whole budget. So 83.5% of the aimed part was calculated by 3D.

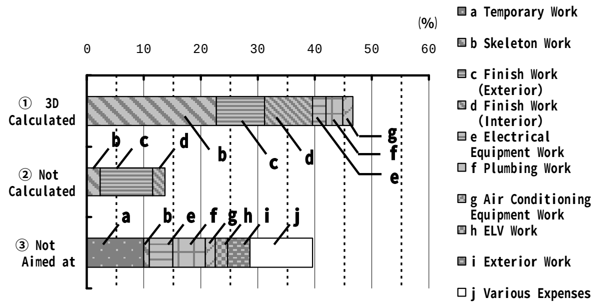

Figure-5 Quantity Ratios of the High Rise Residential Building

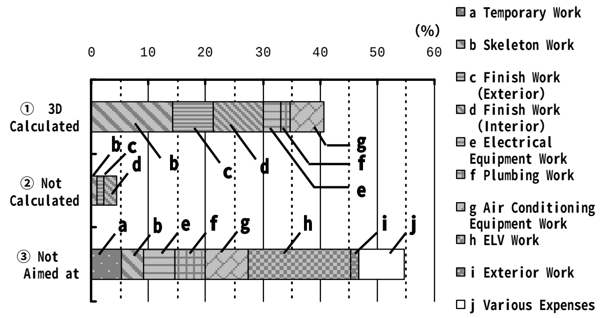

Figure-6 Quantity Ratios of the Laboratory Facility

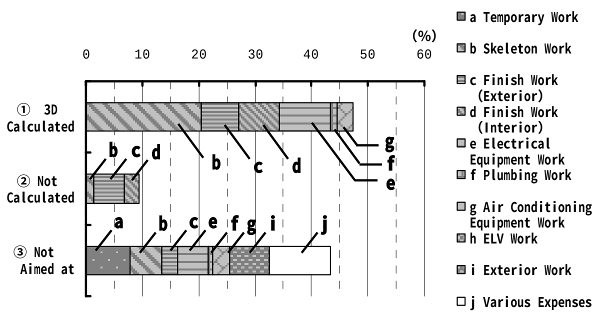

Figure-7 Quantity Ratios of the Industrial Factory

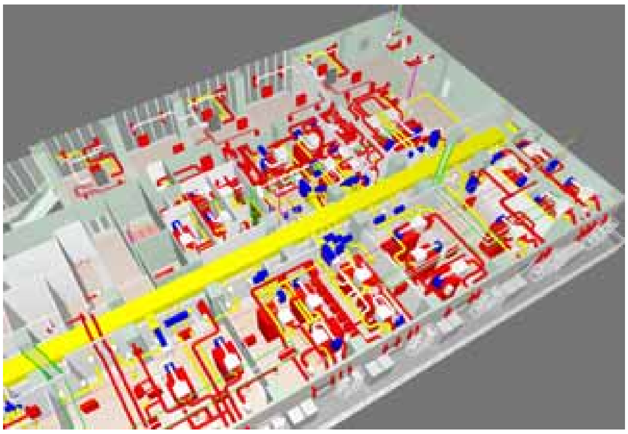
Figure-8 Integrated Rough Model in the Schematic Design

4.4 Overall Comment for the Examples

The ratio of the quantities aimed at 3D modeling in design process is 45~60% of the total budget. The reason of the low percentage of the laboratory facility is that the experiment equipments which were out of the 3D calculated quantities had a high cost ratio. If we ignore the experiment equipments the aimed part is 55 %. So for the three examples almost 60% of the whole budget can be considered to be aimed at 3D modeling. Besides, we were able to calculate the 78%~92% of the items we aimed at which was enough for the cost management. The results are shown in Table-3 according to the types of works.

Table-3 Quantification Output Ratios According to the Types of Works

Type of Work		Residential Building	Laboratory Facility	Industrial Factory
Skeleton Work	Concrete Work	100	100	99
	Formwork	0	100	92.7
	Reinforcing Bar Work	100	100	100
	PCa Work	100	-	-
	Steel Work	-	99.5	92.3
Finish Work	Exterior Finish Work	79.3	86.1	54.6
	Interior Finish Work	47.7	79.1	74.0
Equipment Work	Electrical Equipment Work	100	100	100
	Plumbing Work	100	100	100
	Air Conditioning Equipment Work	100	100	100

(Unit: Percentage)

In case of skeleton work, it is possible to handle the 3D calculated quantities starting from the basic planning and schematic design. After that, you just need to input more detail data into the model as design progresses. The reason why we couldn't quantify the formwork of the high rise residential building was simply the lack of suitable software. As some parts are out of quantification such as water drip cover, caulking, gutter, handrail and protector for water-proofing, the ratio to be calculated becomes low. However, since such parts have a low cost percentage of the total cost, no big gap occurs with the budget. The abovementioned parts can be modeled and quantified if needed, however as it is possible to calculate their values by unit areas at the beginning of the design, they are open to judgment whether to be modeled or not. An integrated 3D model in detailed design is shown in Figure-9.

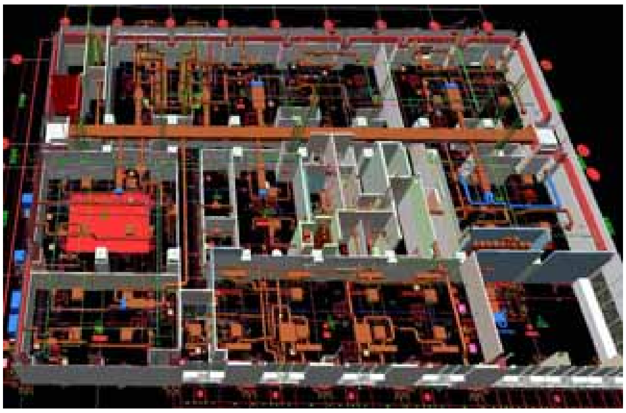

Figure-9 Integrated Model in Detailed Design

5. CONCLUSION

The results of cost management using 3D modeling are as follows:

(1) Currently, in order to solve the problems about design-production process, following the procedure with the new technology 3D modeling is effective.

(2) There is a need of expressing the shape of the building for the unspecialized people, making clear the process of design and handling the quantifications timely in order to discuss with the client and explain why changes have occurred. We realized that 3D modeling was effective to get opinions of various people.

The next task is considered to be as follows.

(1) There are problems about the time to input data into the model and software handling. Regarding the time for input, it is necessary to input data into the model at the early stages in order to avoid gaps between the project and the demands of the client. For the software handling, it is still necessary to improve the 3D modeling software we are using in order to keep up with the changes occurring during the design process.

(2) Although it is possible to get the quantities from 3D model, the final cost depends on the procurement cost. So it is necessary to deepen the relationships more with the procurement department to widen the areas for the quantities to be used.

In this paper, the cost management using 3D modeling is discussed mainly. Next time the issues other then cost management such as relationship with the construction schedule, follow-up after completion and maintenance program will be discussed which are related with the flow of 3D modeling procedure from the very beginning of the project to the following stages up to the maintenance program.

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