

## ANALYSIS OF INFLUENCE ON MECHANICAL DESIGN PROCESS BY BIM SPREAD - CONSCIOUSNESS SURVEY TO BIM BY QUESTIONNAIRE OF MECHANICAL ENGINEER -

Kyosuke Hiyama<sup>1</sup>, and Shinsuke Kato<sup>1</sup>  
<sup>1</sup>The University of Tokyo, Tokyo, Japan

### ABSTRACT

BIM can examine the placement of ductwork and machinery. It significantly increases the efficiency of a mechanical design. In addition, BIM functions as a database to simplify the use of simulation technology. It is important to know the expectations of mechanical engineers who will become frequent users of BIM in the future. A survey was conducted among Japanese mechanical engineers to analyze the expectations of mechanical design using BIM. The results show that many respondents strongly recognize BIM as a three-dimensional CAD program and expect not only the optimization of their design work but also to enhance design functionality.

### INTRODUCTION

In recent years, growing attention has been paid to Building Information Modeling (BIM). The Ministry of Land, Infrastructure, Transport and Tourism (MLIT) in Japan asked to use BIM for a government office building in 2010; thus, it is expected that the use of BIM for architectural design will certainly increase in the future.

Mechanical designs developed using BIM can improve quality and decrease their impact on the environment. As a result, we hope this will provide an opportunity to significantly improve mechanical designs in the whole architectural design field.

To advance research and promote BIM, understanding the expectations of engineers who design air-conditioning systems via BIM is required. This paper presents the results of a survey questionnaire given to mechanical engineers in Japan and examines the direction of BIM research and the development for mechanical design.

### SUMMARY OF A QUESTIONNAIRE

Table 1 shows the entire questionnaire. Q1, Q2, and Q3 contain questions related to the present use of simulation technology and the expectation for its future use. Q5 and Q6 ask for desired functions from BIM. The introduction of BIM is largely effective. However, there is a reason that BIM is not yet widely used. Q7 attempts to determine the main causes for this. Q4, Q8, Q9, and Q10 are the respondents' attributes.

The questionnaire was filled online, and the URL was sent to general design firms, Mechanical Electrical Plumbing (MEP) engineering firms, general contractors (Zenekon in Japanese), sub-contractors (Sabukon in Japanese), and other companies with design facilities. The respondents were limited to mechanical designers and engineers. The period of the questionnaire was 15 days, from July 1st to 15th 2010.

### RESULT AND ANALYSIS

#### **Respondents' Attributes**

There were a total of 100 respondents. Figure 1 shows the results from Q9 according to type of industry. Half of the respondents work at general design firms or MEP engineering firms where the main service is design. The other half work in general construction industries and companies working with building equipment workers and contractors. The breakdown of Q9 is as follows. From five general design firms, 34 people completed the questionnaire, and 8 did not respond. From two facility design firms, 3 took the questionnaire, and 3 did not respond. From five general construction industries, 16 answered, and 12 did not respond. From two building equipment companies, 18 answered, and 3 did not respond. The answers to Q10, which are responses to questions on the respondent's role in the mechanical design process, are shown in Figure 2. Half of the respondents were supervisors and the other half designers or engineers.

The answers reflected the respondents' perspectives of their duties as designers or supervisors. Figure 3 shows the answers from Q4, which inquires about their percent usage of BIM; 88% said "Never". One hundred percent of the respondents answered either "Rarely" or "Never". This result indicates that BIM is not used in the facility design field at all. Figure 4 shows the percent usage by MEP engineers in the USA. Compared to the percent usage of 42% in the USA, BIM use in Japan is extremely low.

#### **Usage of Simulation Technology**

Figure 5 shows the frequency of simulation usage (Q1) with the average rate and difference in box-plot form. It shows that the construction environmental efficiency rating such as CASBEE (Japan Sustainable Building Consortium 2010) is used most frequently

in determining construction, and more than a fourth of the respondents use this simulation technology on all projects. Energy simulation comes second in the list, followed by system simulation, LCA, and CFD analysis. Although some answered that they use LCA and CFD analysis on all projects, three-fourths of the

respondents showed indicated 30% usage. CASBEE, which utilizes Excel, or Energy simulation, which is in high demand, require comparatively less data entry labor. CFD analysis requires more intricate data entry (creating three-dimensional models) than other simulations.

*Table 1 Content of Questionnaire*

<p><u>Questions about usual design work.</u></p> <p><b>Q1. How much (in percentage) do you use the below mentioned technical computing for your design? Please tell us the estimate for roughly the last one year (e.g., Used on half of all projects = 50%.)</b></p> <p>i. Energy Simulation (Annual thermal load calculation)</p> <p>ii. System Simulation</p> <p>iii. LCA (Life Cycle Assessment: LCCO2 etc.)</p> <p>iv. Construction Environmental Efficiency Rating (CASBEE etc.)</p> <p>v. CFD Analysis</p> <p><b>Q2. Please choose the most applicable among the listings below of your reasons to use the 3D indoor environment estimation tool (Multiple answers allowed.)</b></p> <p>- To optimize for a comfortable thermal environment</p> <p>- To optimize the air flow (designs for natural ventilation)</p> <p>- To ensure against creating an uncomfortable thermal environment</p> <p>- To optimize the outdoor wind environment (securing cool outdoors breezes)</p> <p>- To ensure against creating a windy zone (building-induced wind)</p> <p>- To create explanatory documents corresponding to a client's request</p> <p>- Because of company and group policy</p> <p>- Unknown because not used</p> <p>- Other ( )</p> <p><b>Q3. Which one from the list below should be applied to optimize designs (to improve design quality)? (Multiple answers allowed)</b></p> <p>- Energy Simulation (Annual thermal load calculation)</p> <p>- System Simulation</p> <p>- LCA (Life Cycle Assessment)</p> <p>- Construction Environmental Efficiency Rating (CASBEE etc.)</p> <p>- CFD Analysis</p> <p>- Other ( )</p> <p>- None</p> <p><u>Questions about BIM (Building Information Modeling)</u></p> <p>BIM: It is a database of a digitalized 3D building accompanied with attribution data, such as machinery parts and materials data. Today, some software programs are available on the market that can make it possible to automate thermal load calculation and verify the error and problems in overlaying architectural/constructed/facility models.</p> <p><b>Q4. Do you use BIM when you design a mechanical plan?</b></p> <p>- Always</p> <p>- Mostly</p> <p>- Rarely</p> <p>- Never</p> <p><b>Q5. Please choose three from the list below that you think provide the best advantage in using BIM for mechanical designs.</b></p> <p>- It is possible to examine the placement of ductwork/piping and the machinery room. Also, it is easy to check design errors in advance.</p> <p>- It can secure integrity and consistency for design works, design drawings, and specifications, as BIM automatically creates the design drawing and specification during the design process.</p> <p>- It reduces the labor in data entry for thermal load calculation.</p>	<p>- It reduces the labor in data entry for construction efficiency rating tools, such as CASBEE.</p> <p>- It facilitates integration (picking up) or creating an operation plan.</p> <p>- It makes communication between the project team smooth.</p> <p>- It can be used for a design presentation to a client.</p> <p>- It can be used for facility management.</p> <p>- Other ( )</p> <p><b>Q6. Assume that the BIM software listed below exists on the market.</b></p> <p>Product 1: Automation of ductwork placement and energy simulation</p> <p>Product 2: Automation of ductwork placement and CFD analysis</p> <p>Product 3: Automation of CFD analysis and energy simulation</p> <p><b>Q6-1. Please choose one of the BIM products above that your company would want to use most.</b></p> <p>- Product 1</p> <p>- Product 2</p> <p>- Product 3</p> <p><b>Q6-2. Please choose a secondary product you want to use.</b></p> <p>- Product 1</p> <p>- Product 2</p> <p>- Product 3</p> <p><b>Q7. Please choose the elements you think would be obstacles in using BIM in the mechanical design process (multiple answers allowed.)</b></p> <p>- Client requests are few.</p> <p>- There is no time to evaluate or examine BIM technology in the company.</p> <p>- High in initial investment cost.</p> <p>- BIM function does not match business outline.</p> <p>- Present design method is enough.</p> <p>- Present CAD software is not compatible with BIM software.</p> <p>- The BIM software does not fit with Japanese industrial standards.</p> <p>- Difficult to use BIM software.</p> <p>- There is no time to master and train on BIM software.</p> <p>- Difficult to find a competent CAD operator or subcontractor.</p> <p>- Other field (Architectural design, Construction design) is not using BIM.</p> <p>- Other( )</p> <p><u>-Lastly, questions about yourself</u></p> <p><b>Q8. Please tell us your company and division name. *optional e.g.:. OO,Inc. OO division</b></p> <p>( )</p> <p><b>Q9. Please choose a type of industry.</b></p> <p>- General design firm</p> <p>- MEP engineering firm</p> <p>- General contractor (Japanese Zenekon)</p> <p>- Subcontractor (Japanese Sabukon)</p> <p>- Other ( )</p> <p><b>Q10. Please choose your role in facility designing.</b></p> <p>- Supervisory position (position of responsibility in design quality)</p> <p>- Designer or engineer (position of actual designing, requires the confirmation and advice from a supervisor)</p> <p>- Assistant (position of assisting designers/engineers and supervisors)</p> <p>- Other ( )</p>
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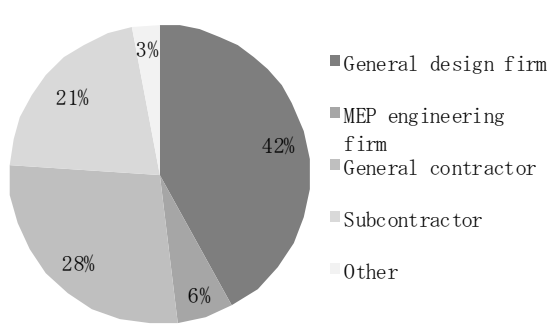


Figure 1 Q9: Please choose a type of industry

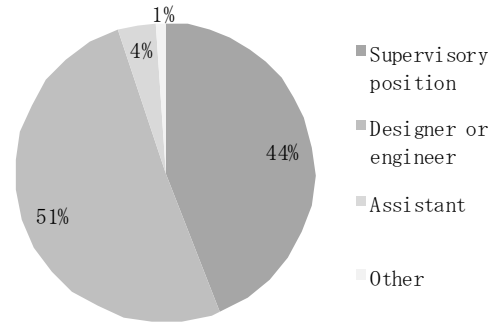


Figure 2 Q10: Please choose your role in facility designing

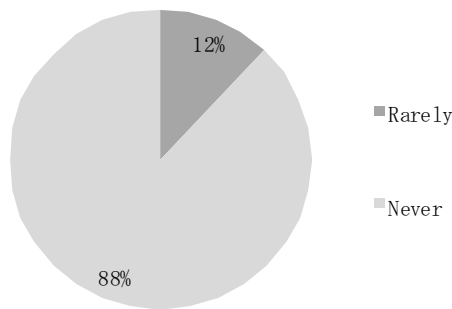


Figure 3 Q4: Do you use BIM when you design a mechanical plan?

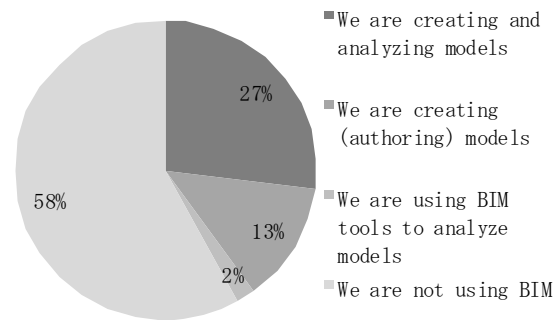
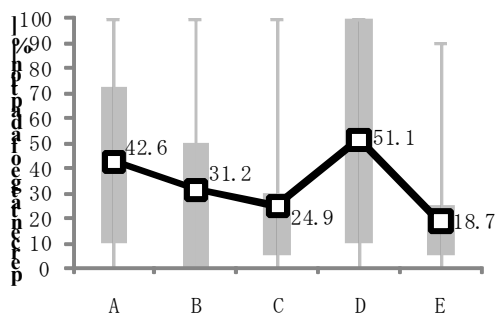
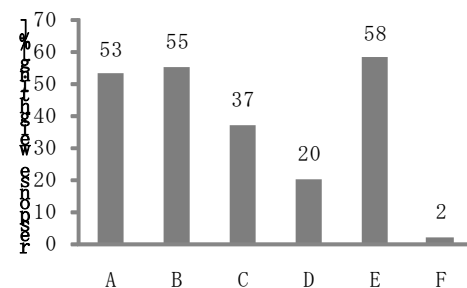


Figure 4 BIM Adoption and Usage in USA<sup>1)</sup>  
(McGraw\_HILL Construction 2009)



- A. Energy Simulation
- B. System Simulation
- C. LCA
- D. Construction Environmental Efficiency Rating
- E. CFD Analysis

Figure 5 Q1: How much do you use the technical computing for your design?



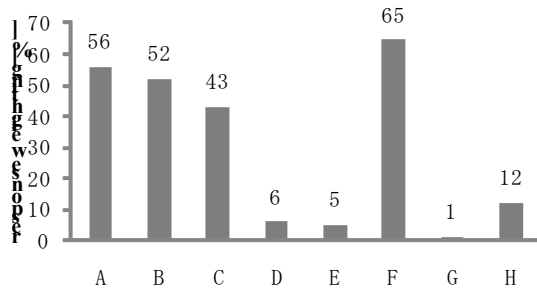
- A. Energy Simulation
- B. System Simulation
- C. LCA
- D. Construction Environmental Efficiency Rating
- E. CFD Analysis
- F. None

Figure 6 Q3: Which one from the list should be applied to optimize designs?

Although it changes according to clients' demands and it is difficult to infer simply, the frequency of simulation use seems to drop significantly with more intricate data entry. Figure 6 shows the results from Q3 concerning the expectations from using simulations in the future. CFD analysis received the most interest, followed by system simulation and energy simulation. Compared to LCA (both LCA and CFD analysis showed low usage in Q1), CFD analysis has hope for design optimization, even with intricate data entry. Using BIM to automate data entry for CFD analysis has great potential.

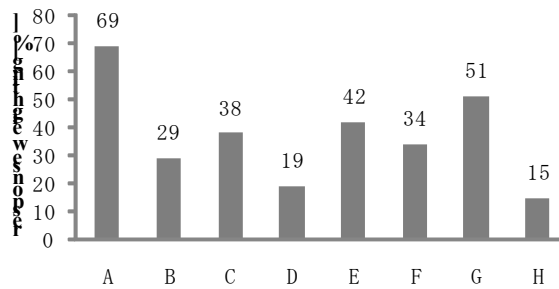
Because there was high usage reported in the construction environmental efficiency rating in Q1, its result for future usage was low.

Figure 7 displays the reasons for using three-dimensional indoor environmental estimation tools such as CFD analysis (Q2). A large amount of respondents indicated that it is useful in presenting a design to a client, followed by thermal environmental analysis, natural ventilation, and indoor environmental analysis. It was also shown that it is rare for mechanical engineers to analyze the outdoor wind environment. To promote CFD analysis in



- A. To optimize for a comfortable thermal environment
- B. To optimize the air flow (designs for natural ventilation)
- C. To ensure against creating an uncomfortable thermal environment
- D. To optimize the outdoor wind environment (securing cool outdoors breezes)
- E. To ensure against creating a windy zone (building-induced wind)
- F. To create explanatory documents corresponding to a client's request
- G. Because of company and group policy
- H. Unknown because not used

Figure 7 Q2: Please choose the most applicable among the listings below of your reasons to use the 3D indoor environment estimation tool



- A. It is possible to examine the placement of ductwork/piping and the machinery room. Also, it is easy to check design errors in advance.
- B. It can secure integrity and consistency for design works, design drawings, and specifications, as BIM automatically creates the design drawing and specification during the design process.
- C. It reduces the labor in data entry for thermal load calculation.
- D. It reduces the labor in data entry for construction efficiency rating tools, such as CASBEE.
- E. It facilitates integration (picking up) or creating an operation plan.
- F. It makes communication between the project team smooth.
- G. It can be used for a design presentation to a client.
- H. It can be used for facility management.

Figure 8 Q5: Please choose three from the list below that you think provide the best advantage in using BIM for mechanical designs

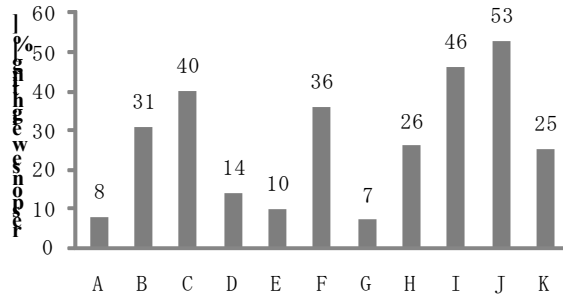
projects, it is important to demonstrate that BIM is useful in visualizing designs for clients and convenient for analyzing indoor environments.

### The Expectations of Facility Design Engineers for BIM Development

Figure 8 shows the responses to Q5, a question about what the respondents think the advantages of BIM are. "It is possible to examine the placement of ductwork/piping and the machinery room. Also, it is easy to check for design errors in advance" received the most responses, followed by "It can be used for a design presentation to a client". These two answers came first because the respondents seem to have an idea of BIM as a three-dimensional graphic tool. "It reduces the labor in data entry for thermal load calculation" and "It facilitates integration (picking up) or creating an operation plan" ranked next in importance. BIM might be thought of as a database function. One of the selections, "It reduces the labor in data entry for construction efficiency rating tools, such as CASBEE", is also a database function. As mentioned above, because it is already used frequently, it did not appear as an advantage of using BIM. It also showed that engineers do not feel that CASBEE data entry constitutes much of their labor. "It can be used for facility management" ranked very low in the results. However, The General Service Administration (GSA) in the USA guidelines list facility management as one of BIM's merits. Here, the respondents did not demonstrate awareness of added value other than the optimization of their present design process. Similarly, research in the

USA did not show that a client has many demands for Operation and Management (O & M) (McGraw\_HILL Construction 2009).

It is important to develop an additional function in BIM if we want to promote its use. Thus, we asked what kind of function in BIM an mechanical engineer desires. We conducted a conjoint analysis, using facts about functions, such as "Automation of ductwork placement," "Automation of energy simulation", and "CFD analysis automation" (Q6). We used PASW Conjoint 18 software for this analysis. "Ductwork" here represents only the regulated work in mechanical design. The desire to automate the placement of ductwork will result in reduced labor in mechanical design. "Energy simulation" is necessary for design optimization. Many projects have already incorporated this feature. This simulation makes a process more efficient. Although "CFD analysis" is also necessary for design process optimization, it is used less frequently than the other functions. The addition of CFD analysis to previous design processes will likely improve and optimize the mechanical design itself. Table 2 shows each the value of each function. When a respondent chooses a product accompanied with each function and indicates a high value, it means that the decision has a big influence. The results show that energy simulation was highest in value, while duct and CFD analysis were almost the same. Overall, the engineers expect energy simulation to be more efficient and applicable than previous design technologies by using BIM.



- A. Client requests are few.
- B. There is no time to evaluate or examine BIM technology in the company.
- C. High in initial investment cost.
- D. BIM function does not match business outline.
- E. Present design method is enough.
- F. Present CAD software is not compatible with BIM software.
- G. The BIM software does not fit with Japanese industrial standards.
- H. Difficult to use BIM software.
- I. There is no time to master and train on BIM software.
- J. Difficult to find a competent CAD operator or subcontractor.
- K. Other field (Architectural design, Construction design) is not using BIM.

Figure 9 Q7: Please choose the elements you think would be obstacles in using BIM in the mechanical design process

Table 2 Value of each function

Functions	Value
Ductwork	31.3
Energy simulation	38.3
CFD analysis	30.3

### Obstacles to BIM Use

Figure 9 shows the results from a question regarding obstacles to using BIM. The most selected answer was “Difficult to find a competent CAD operator or subcontractor”. “Present CAD software is not compatible with BIM software” was the secondary reason. There are many people who feel that their company is not ready for new technology. These answers were followed by “There is no time to master and train on BIM software”, “High in initial investment cost”, and “There is no time to evaluate or examine BIM technology in the company”. The respondents seem to think that the effects do not warrant the costs of this technology. On the other hand, the survey shows low numbers in “Client requests are few”, “BIM function does not match with business outline”, and “Present design method is enough”. Thus, we can see here that respondents understand the need for the use of BIM. To spread BIM use, it is important to create a suitable environment for BIM. In addition, we need to demonstrate its effectiveness in terms of both time and cost to each company.

### DISCUSSION

We will examine the important points for spreading the use of BIM in the mechanical design process in

this chapter. We examine the optimization of designs when BIM is implemented. A mechanical design can be improved as follows:

- 1) Confirmation of positioning by a three-dimensional CAD function.
- 2) Facilitation of data sharing between software (easy data entry of simulation).
- 3) Seamless database function from design to operation management.

Figure 8 (Q5) shows that there were many respondents who believe BIM is advantageous in identifying problems in ductwork. This is the primary reason to use BIM for design optimization. As Table 2 (Q6) shows, an expectation for BIM software is not only the automation of ductwork placement but also energy simulation. Thus, the second listed advantage would be possible after improving current BIM software. The software needs to be of higher quality, and the function needs to be expanded so that BIM can be recommended to the mechanical design field more. There were only a few respondents who thought that the advantage of BIM is that it can be used for facility management (in Figure 8 (Q5)). This leads to the third listed advantage, which is not well known. Because BIM is not well recognized even in the architectural design process, it is still too early to expect end-users in facility management. Today, material investment is dropping with the low numbers of new building construction projects. Thus, we believe that it is important to add value to construction by enriching service. The facility management of BIM is part of this. It is necessary to demonstrate the possibility of using BIM for industrial development and to present how it works as an advantage.

### CONCLUSION

Other countries have recently started to shift architectural design methods from creating two-dimensional drawings and specifications to using BIM database construction. However, Japan is responding slowly. Particularly in the air-conditioning design process, BIM is barely used. BIM has the advantage of significantly improving design functionality. In addition, we can expect to connect design optimization with the innovation of simulation technology using database functions in BIM. Thus, we conducted a survey of 100 mechanical engineers to investigate the use of BIM in the future. A summary of the results is shown below:

- 1) 12% of respondents have used BIM before. However, a significantly lower rate of use was observed in the facility design field in Japan.
- 2) Below 20% reported the use of CFD analysis. However, about 60% reported that to improve the design process, it is highly desired for the future. Users can improve the frequency of

using CFD analysis with the efficient data entry provided by BIM.

- 3) Mechanical engineers understand that the primary advantage of using BIM is to be able to confirm the placement of ductwork/piping and to provide documents for a client using three-dimensional functions.
- 4) Air-conditioning design engineers hope to use more convenient design tools, such as energy simulation, more than the automation of format works, such as the automation of ductwork placement.
- 5) Obstacles to adopting BIM include worries about accepting technology in their present conditions, lack of CAD contractors, and problems with software compatibility. On the other hand, respondents believe BIM is a good tool for presenting their designs to clients. They also understand that BIM can provide many advantages to design optimization.

### ACKNOWLEDGEMENT

I would like to express my deepest gratitude to Mr. Kentaro Suga from Arup Japan, Mr. Makoto Ohura from Autodesk, Inc., Dr. Mutsumi Yokoi, Dr. Hikaru Kobayashi, Mr. Takeshi Ogawa, Mr. Keiko Sugawara from Taisei Corporation to help for the questionnaire.

### REFERENCES

- McGraw\_HILL Construction, 2009, Smart Market Report, The Business Value of BIM
- Japan Sustainable Building Consortium, 2010, Comprehensive Assessment System for Building Environmental Efficiency CASBEE for Heat Island Relaxation. Institute for Building Environment and Energy Conservation (IBEC), Tokyo, Japan