3D Systems For a Safer and More Productive Construction Site

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The productivity of the construction industry has been falling since the 1990s, and the construction industry has more fatal workplace accidents than any other industry. Construction companies in advanced nations have positioned overseas projects as an important part of their business growth strategies. Recently, new technologies such as Building Information Modeling (BIM), Virtual Design Construction (VDC), Cloud Computing and Tablet Terminals are being introduced in the construction phase as well as the planning and design phases. 3D systems which can use 3D models of buildings and structures on tablet terminals or can document work instructions for on-site management are expected to solve the challenges to productivity, safety, and positioning in the construction industry.

1. Subject and Growth Strategy of Construction Industry

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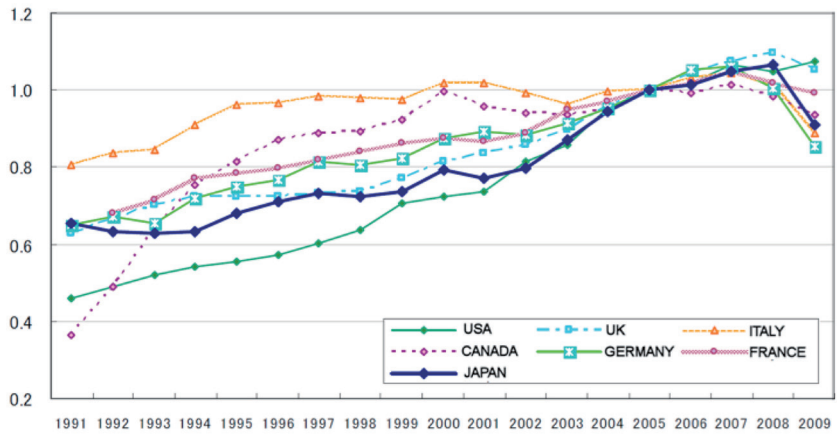
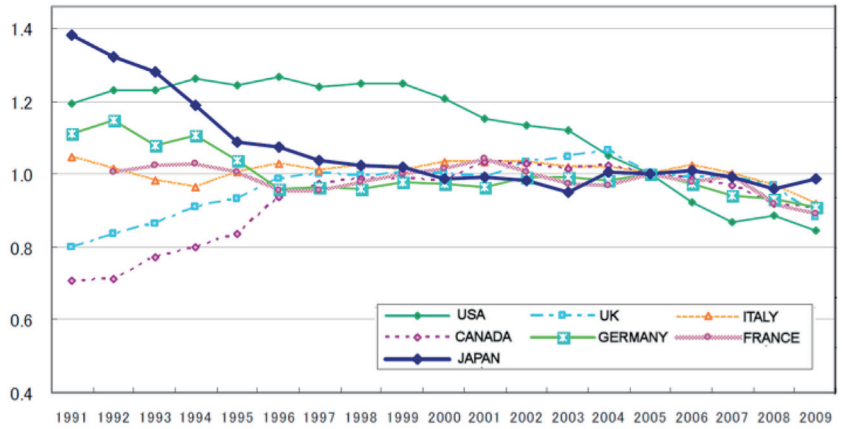
While the labor productivity of the manufacturing industry has gone up steadily since the 1990s, the productivity of the construction industry has been falling. The rise in labor productivity can be attributed to the introduction of 3D CAD and ICT (Information and Communication Technology) systems, especially in the group of seven industrialized countries which include the United States, Canada, Germany, France, Great Britain, Italy and Japan.

The manufacturing process has also advanced in robotization and automation while reducing the need for trial production. And experimentation has sharply reduced risk with digital prototyping, analysis and simulation, thus shortening the product development period while consistently improving productivity.

On the other hand, the construction industry still continued to design with paper drawings and employ labor-intensive work at construction sites. As a result, labor productivity gradually worsened since they did not have the benefit of using ICT.



Labor productivity comparison of the manufacturing industry in the Group of Seven industrialized countries.
(Data: "International Comparison of Labor Productivity, 2011 Edition", Japan Productivity Center)



Labor productivity comparison of the construction industry in the Group of Seven industrialized countries.
(Data: "International Comparison of Labor Productivity, 2011 Edition", Japan Productivity Center)

Labor Education and Improvement of Safety at Construction Sites.

The construction industry has more fatal workplace accidents than any other industry. The main causes of accidents in the construction industry are falls from high places, being hit by vehicles or construction machinery, and injuries by falling objects.

Since construction industry work is mainly done in temporary structures built outdoors with custom made products, serious accidents tend to occur that are unlike those in the manufacturing industry.

The most important part of on-site management is to prevent accidents and save valuable human lives. As various workers, such as scaffolders, form workers, concrete workers, exterior and interior contractors, enter construction sites, they are often unfamiliar with work procedures and methods and do not have enough information about the work procedures of other workers. This lack of information contributes to construction accidents.

1.2 Internationalization of Projects

While the construction market is saturated in advanced nations, there is strong construction demand in Asia, the Middle East, and South America. Construction companies in advanced nations have positioned overseas projects as an important part of their business growth strategies.

Obviously, there are often language barriers in overseas projects. Project members sent to the construction site have difficulty communicating in local languages. Site workers who come from various countries speak a variety of languages and struggle to communicate in a common language.

Since there are verbal communication challenges in overseas projects, visual communication methods that can be easily understood are sought, as a more practical alternative. Computer graphics and animation are desirable approaches to solve the problem.

1.3 BIM(Building Information Modeling) introduced at Construction Sites

BIM (Building Information Modeling) has been increasingly introduced in global design firms, contractors and material manufacturers from the late 2000s as a tool to improve productivity of the construction industry. BIM has helped to greatly improve productivity in the design phase due to its ability to visualize designs and create 3D images of a building after completion, as well as automate creation of drawings, quantity take-offs, analysis, simulations, and other processes, using its property information. BIM is also improving the productivity of construction by "front loading" which solves the problems in the construction phase during the design phase.

BIM is introduced not only in the design phase but in the construction stage also. For example, full BIM that include artistic design, structural design, and MEP design are utilized at construction sites. The engineers working for general contractors and sub-contractors examine construction procedures and check if there is any interference between members in crane work using 4D construction simulation.

Comparatively, BIM has focused on the design and engineering phases and Virtual Design Construction (VDC) has focused on the construction phase and overall project management. Those two methodologies should be integrated into one methodology to achieve more efficiency. BIM and VDC should be used at the same time to ensure the collaboration of the right people and the right time for maximum efficiency.

1.4 Prevent Rework and Cut Costs with Prefabrication

After the front loading of BIM plus VDC is put into practice, "site adjustment work" to fit pipings, ducts, and other MEP tasks to site conditions will no longer be needed. All components can be prefabricated in factories.

Prefabrication of components simplifies site work and improves safety while increasing quality. And the need for rework is almost eliminated.
According to a major MEP contractor, 30 percent of their work had to be done as rework using conventional construction procedures. Therefore, prefabrication also has the effect of turning rework losses into profits.

1.5 Briefing: Growth Strategy of Construction Industry by Introduction of ICT in Construction Sites

The productivity of the construction industry has been falling over the past 20 years, and there are many more industrial accidents at construction sites compared with other industries. As domestic construction markets in major, advanced nations become saturated, participation in overseas projects is becoming more and more important to growth strategies.

BIM has been introduced in design firms and design departments of contractors at an early stage. It has also been used at construction sites. BIM plus VDC provide the advantage of being able to visualize design and construction procedures using 3D computer graphics and animation. There is also the merit of "front loading" which finds construction problems in advance and solves them in the design phase. When BIM plus VDC is used at construction sites, project members from the site master, to forepersons, to site labors and others, can more easily understand the design and construction procedure information in a common way, compared with using conventional paper drawings. It also helps to prevent industrial accidents.

As BIM plus VDC eliminates “site adjustment work”, work shifts from construction sites to factories for prefabrication, thus reducing losses due to rework. Safety at construction sites also improves as the number of site workers decreases.

Though construction industry productivity has been decreasing over the past 20 years, it can be improved with the introduction of Information and Communication Technology (ICT) at construction sites.

2 Introduction of ICT in Construction Sites by Tablet Terminals

2.1 Effects of Tablet Terminals at Construction Sites

McGraw-Hill Construction of United States conducted research on the use of mobile terminals at construction sites by contractors in August, 2012. It shows clearly that use of mobile terminals is increasing quickly. The answers from the respondents, most of whom were leaders and managers, showed that 97% of general contractors were using mobile terminals at construction sites.

Although 87% of respondents of specialty contractors answered that they were using mobile terminals, 91% of non-users answered that they would probably use mobile terminals by 2015. This means that the introduction rate in specialty contractors will be the same as general contractors.

Although the use rate of smart phones as mobile terminals is high at this time, tablet terminals look to be dominant in the future. The use rate of tablet terminals is likely to double in three years. Among respondents from companies with sales of $US10 million or more, 62% would like to introduce iPads and 32% would like to introduce other tablet terminals by 2015.

Contractors think that the use of mobile terminals at construction sites would enhance productivity of various jobs. The top three productivity improvements noted are "communication and problem solving", "collaboration", and "human resource management and process control."

Tablet terminals have various functions and equipment features including: communication connections with the Internet, LAN and WAN, large size screen displays for showing drawings and technical data clearly, camera and microphone to record site’s condition with photos and movies, a GPS that shows correct position, and various sensors which can detect acceleration, lights, and other stimuli. These functions are all suitable for construction sites.

Utilized in combination with cloud computing, tablet terminals will improve productivity at the front line on construction sites. For example, engineers and site workers can see drawings, BIM models, and animations whenever and wherever they want. They can also upload photos and inspection reports that need to be recorded for on-site management.

As a result, executive managers do not need to return to their on-site office repeatedly in order to access data. A manager of a major general contractor pointed out "Not to return to the on-site office is the greatest merit of tablet terminals."

One tablet terminal which carries a large liquid crystal display (LCD) can substitute for a whole set of drawings, cameras, data sheets, field notes, and even a personal computer. It is lightweight, weighing a few hundred grams. So it is an ideal tool for on-site management.

2.2 Extensive Introduction of Tablet Terminals at a General Contractor

At the on site management of construction sites, it wastes a lot of time and energy to walk with multiple documents such as drawings and data, and then return to the on-site office in order to get the required information. On site managers still have a lot of work to do to correct drawings, create documents, and other drafting tasks even after they return to the on-site office when the site work is complete.

Japanese general contractor, Obayashi Corporation started to change the work style of their on-site managers by using ICT (Information and Communication Technology) to eliminate the inconveniences noted above and to increase efficiency. Starting in August 2012, the company provided about 3,000 tablet terminals to all managers at sites.

Technical information such as standards and construction drawings and safety information are installed in the tablet terminals. On-site managers can also access drawings on the server with cloud computing, check drawings and reference drawings on the tablet terminals.

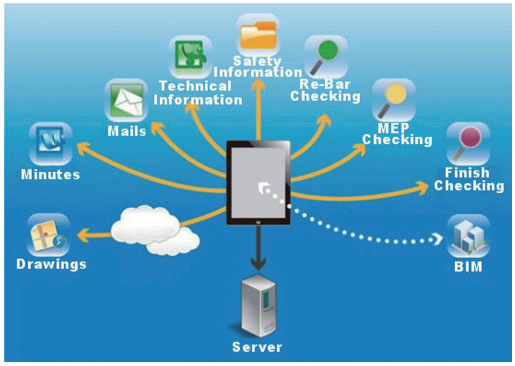
The system will be connected to the site inspection support system which is composed of re-bar checking, MEP (Mechanical, Electrical, Plumbing) checking, and finish checking. The on-site managers can make comments on drawings and save that data on-site.

Moreover, work instructions which contain photographs, drawings, execution schedules, meeting records, and meeting records, for example, are displayed visually on tablet terminals so that on-site managers can easily explain conditions to workers. It is expected that these instructions and correction confirmations for workers are recorded as data and stored, eliminating double input to personal computers. This can sharply reduce the work needed to make reports.

If it is possible to check information required for on-site managers, and to conduct business processes, the work style at construction sites will become more efficient, and enable executive managers to cope with matters happening at the site in real time.

The terminals use wireless LAN (Wi-Fi) for communication and connect to the Internet via the access point at the on-site office. A digital certificate and MDM (Mobile Device Management) are included in the terminals, and security is raised by limiting the connection to the network to registered terminals.

Data is protected against theft or loss with a password, automatic formatting, and a remote control service called "remote wipe" which can eliminate the data in the terminal by remote control. Use of BIM on the terminals is also planned.



Images courtesy of Obayashi Corporation

3. Use of BIM, AR (Augmented Reality), 3D Technologies

3.1 CALTRANS : Animation of Cable Installation Procedure of the Bay Bridge

The San Francisco Oakland Bay Bridge, which opened in 1931, is a main traffic artery that has 280,000 cars pass over it every day. The bridge is divided into east and west parts at Yerba Buena Island. The eastern part of the bridge is being re-constructed.

The bridge renovation used the suspension bridge structure that supported the main tower with an anchor. The cable is fixed at the easternmost end of the beam and goes around the beam passing over the main tower, to the westernmost part of the beam. Then it returns back over the tower and is fixed at the easternmost end of the beam. The cable is composed of "strands" which bundle the wires together. More than one hundred strands are accumulated from the bottom according to a predetermined order.

Among the various software used for this project, animation software that illustrates construction procedures with BIM plays an important role. Very extreme construction work occurs in which old structures are removed and new structures are installed in a couple of days over a weekend, so that the bridge is opened to the public at the beginning of the next week. Failure is not allowed. Animation helps all project members to clearly understand the procedure of the construction work.

Information sharing among project members, including site workers, is facilitated by BIM and animation. It enables team members to finish work earlier than planned while limiting the road closure time. BIM and animation would also effectively support traditional construction industry technology.

3.2 Shimizu Corporation Chiba Branch: Simulate Erection of Steel Frame Erection and Re-Bars with BIM

The Chiba Branch of Shimizu Corporation has tackled 3D CAD use in the construction phase since 2003. BIM is utilized for creation of construction drawings at 100% of new buildings, and is also used to automate quantity takeoff of concrete volumes and molds to check estimates.

Creation of the “total drawing” with BIM that combines architecture, structure, and MEP, visualizes all types of work. It helps project members understand work processes of other contractors and solves problems prior to the construction phase with “front loading”. At a construction site surrounded by buildings, space for crane work is limited to within the site boundaries. In such cases, Shimizu simulates the crane work step-by-step for each team member using BIM to plan construction procedures. This is the first use of BIM at construction sites.

3.3 Briefing: 3D Technology Usage Trends at Construction Sites

It has been often said that even if BIM software or 3D CAD is introduced in the design phase, 3D models must be converted to paper drawings for use at construction sites. Therefore, even if 3D models of buildings or structures are made in the design phase and there are various merits of 3D model use at construction sites, these benefits have not been recognized and realized in the current industry conditions.

Recently, BIM are now being used on small and highly efficient tablet terminals at the front line of construction sites. Tablet terminals help people to check the settlement of components and confirm construction procedures on the site and explain issues to site workers. Visual explanation is easily understood and helps prevents re-work. Also, the visual communication tools address the problems of language incompatibility, especially at overseas projects, and help prevent industrial accidents.
Information Technology literacy of construction workers has increased with the use of tablet terminals. Workers are familiar with the operation of smart phones, which enable scrolling, expansion, reduction, and others viewing functions with two fingers. Smart phones can now recognize facilities data. Today, construction workers understand that it is more efficient to use the visual expansion, reduction and rotation techniques on the tablet terminal than it is to refer to paper drawings.
Use of BIM at construction sites, where most of the project budget is spent, will further increase construction productivity.

4. System Required at Construction Sites in Near Future

It is expected that there will be a spread of information technology to construction sites through the use of tablet terminals, cloud computing, BIM software, and 3D CAD, providing a full-scale increase in productivity and prevention of industrial accidents.
The following considerations are useful for implementing a successful 3D Construction System on upcoming projects.

4.1 System Usable on Tablet Terminals at Construction Sites and Factories

Traditionally, paper drawings have been used at construction sites and factories. But because paper drawings are bulky and heavy, only a limited number of drawings could be created. Therefore, every time someone needed to refer to a drawing another drawing set had to come out, resulting in a significant loss of time and labor by returning to the on-site office.

Moreover, when the contents of the design are changed, the changes may not be reflected in all parts of the project drawings.

If drawings and technical data are uploaded on a cloud server, all project members can access and refer to the latest drawings and data from tablet terminals. The productivity at construction sites increases by not returning to the on-site office, and problems from using old versions of drawings are eliminated.

4.2 System Helpful to Communication with Foreign Workers

For the construction firms from advanced nations, overseas projects serve as a major growth strategy. However, there is a limit to the verbal communication possible among site workers. Many languages are spoken by workers from various regions and different countries.
Under these challenging verbal communication conditions, the explanation of work instructions for construction procedures using 3D drawings or animation can explain specific procedures to many people using graphics instead of words, but images. Understanding becomes more certain. The productivity of construction sites will be raised and industrial accident prevention improved.

4.3 System Enables Use of BIM at Construction Sites

If the Building Information Models created in the design phase can be referred to on tablet terminals, then the size, cross-sectional shape, or other aspects of the drawing can be correctly seen at construction sites. Moreover, as images of completed work are visually shown in advance of construction, the construction goal can be shared among workers of different disciplines, helping to prevent the need for re-work. Methods such as posting printed computer graphics of completion images at construction sites, and projecting computer graphics during preconstruction meetings have been used. By using tablet terminals and cloud computing, Building Information Models can be used to give clear instructions to workers, which makes their understanding more certain and they can respond to design changes promptly. By using a Building Information Model at construction sites, design changes at the construction site can be fed back into the model and the "as built information" can be made available for the facility management phase.

4.4 System Helpful to Quickly Educate Young Workers

The number of young people who choose construction professions has been decreasing every year along with the percentage of the young workers who have a fundamental knowledge of architecture or civil engineering. If new workers education and daily work instructions are paper-based drawings, they will find it difficult to understand the contents, contributing to failures and accidents at the construction site.

However, a graphical explanation to young workers using 3D models for education and work instruction will better their understanding of their work procedures and the work procedures of others. This leads to a reduction in industrial accidents, such as falling from high places, contact with construction machinery or vehicles, or accidents by falling / flying objects while also increasing productivity.

4.5 Briefing: Expected System to be Developed by Vendors

In summary, the construction industry expects most vendors to develop a system which can use 3D models of buildings and structures created by BIM software or 3D CAD on tablet terminals or documented in work instructions for on-site management.
While such a system enhances the productivity in the construction stage, improving Q (quality), C (cost), D (delivery), S (safety), and E (environment) of construction work increases overall corporate value.
With this system, Building Information Models made in the design phase will be also used in construction, operation, and facility management.

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Graduated from Kyoto University with a Masters Degree in Engineering in 1985, Ieiri worked at JFE Engineering as a civil engineer and at Nikkei Business Publications as editor for 25 years. He became a freelance journalist specializing in BIM and Information Communication Technology for the construction industry in 2010. His official blog site is "Construction IT World" (www.ieiri-lab.jp)