

Case Study of Management System Improvement for Plant Construction - User Needs Identification through Field Observation

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Abstract

Hitachi has adopted IT systems for improving reliability and work efficiency at power plant construction sites, and these have demonstrated various administrative advantages over paper-based work flows. On the other hand, sites that have adopted IT systems have also experienced problems, such as use of unexpected work practices and excessive workloads being placed on certain workers. This case study describes the application of ethnographic research including field observation and interview to develop next-generation construction management systems. No similar studies have been published that described the details of ethnographic approach in such complex working environment. The in-depth research activities revealed gaps between what the systems provided and what was actually needed by on-site workers. This article discusses in details how these underlying problems were identified and what approaches were taken to improve the management systems.

Keywords

Ethnographic Research, Human Centered Design, Plant Construction System

1. Introduction

Ensuring that work is performed to an extremely high standard is necessary for power plant construction in order to guarantee work accuracy. Achieving this requires close management of whether worker competency and equipment satisfy the requirements specified in the work instructions. This in turn requires rigorous recording of data that includes the names of workers and the equipment they used. The construction of a power plant is a huge project that may last for five years or so. Moreover, it involves several thousand people and huge number of tasks and processes, so efficient management is required to deal with the complications.

With the aims of improving the reliability of production and quality of workmanship at power plant construction sites, and to enhance traceability and the efficiency of production and construction management, Hitachi has been independently developing and implementing IT systems since the 1990s. As a result, projects are now able to access and interpret information such as the latest design details or real-time updates on work progress at the construction site, facilitating fast and accurate decision-making.

When the newly developed systems were introduced at actual sites, however, new problems arose. These included the systems being used in ways that differed from what was assumed in the design, and excessive workloads being placed on certain personnel, for example. In response, Hitachi adopted user experience design techniques in the development of its next generation of construction management systems in order to ensure that the systems took adequate account of the viewpoints of site users. Specifically, the development included the following four processes: (1) use of ethnographic research and interviews based on on-site observations to determine how to take account of the actual work practices of site users and the underlying problems faced by the site, (2) identification of both explicit and latent user needs, (3) establishment of development policies and the development of ideas for next-generation systems, and (4) use of prototypes to undertake repeated cycles of user evaluation and feedback of results.

This article describes the methodologies and effectiveness of ethnographic research used to identify the underlying problems and latent needs at construction sites, and its role in enhancing the capabilities of power plant construction management systems.

There are some IT systems that are similar to that of Hitachi, such as Toshiba's 6D CAD, JGC's 4D CAD System, and Chiyoda's i-PLANT21. The overviews of the systems are introduced in their websites or some articles such as *Toshiba Review* written by Ikura (2010). However, they do not provide detailed information about how they launched the system on site, or how the system overcame the challenges of workers. Through describing these processes, this article suggests how people involved in the operations management of complex working environment can solve challenges on site by identifying existing problems and underlying root causes through ethnographic approach.

2. Ethnographic Research

Ethnographic research is a social science methodology for explaining the culture and lifestyle of specific groups (such as a nation or society) in terms of anthropology and sociology. It involves observing and conducting interviews with people in the target group while living among them for an extended period of time.

In recent years, the introduction of various products and services (such as information systems) has changed the way people work and go about their lives. This has led to new problems associated with the relationships between information services and people or with the relationships between people that are mediated by these systems. When used in the development of products and services, ethnographic research can create a picture of the structure and processes of various phenomena through detailed observation of people's real actions, and through analysis of the acquired data. Moreover, by identifying patterns that relate to frequently occurring problems and understanding these at a conceptual level, it is possible to shed light on the underlying issues involved in enhancing the user experience provided by products and services that are under development.

The problem with attempting to ascertain the content of work solely through interviews is that the results tend to be biased toward those aspects of the work of which the worker being interviewed is consciously aware (the explicit aspects, in other words). Ethnographic research, in contrast, uses researchers unfamiliar with the culture and rules of the work being studied to observe what the relevant people actually do. This means that the researchers can acquire information about implicitly presupposed sets of values and about behaviors that are performed unconsciously, and in doing so they can acquire a complete picture of the work being done by the organization, including its latent needs.

3. Ethnographic Research at Power Plant Construction Site

The following sections describe the ethnographic research procedures conducted at a power plant construction site.

3.1. Understanding the Outline of Work at Power Plant Construction Site

Before starting the research, the ethnographers attended four days of lectures where they learned the basic knowledge of work procedures and processes needed to observe the power plant construction work, details of administrative arrangements and other work practices, and details of the construction management systems at the site, including how they were intended to be used. As part of formulating their research plan, they also visited a power plant construction site to gain a first-hand appreciation of the project scale and on-site conditions.

3.2. Research Target

The construction of a power plant is a huge project, incorporating as much as 150 km of pipes, for example, and one that involves a wide variety of people. In the case of piping, for example, these include the groups responsible for pipe manufacturing, for the storage of pipes shipped from the manufacturer, for pipe assembly, and for piping quality control. As the plant designer, Hitachi sits at the top of this hierarchy and is responsible for coordinating a large number of Hitachi and subcontracting companies whose roles are first-, second-, or third-tier. As attempting to conduct research throughout such a huge project would be impractical, the study is instead done in stages. Accordingly, the first work area selected for research was the piping fitting up of assembled pipes, a process that is subject to the most stringent of quality control.

The piping fitting up is a specified method to align the joints between pipes, valves, pumps, and other components, and the procedure is defined as below (see Figure 1).

- (1) Issuing Piping Fitting up Requirement/Check Sheet: A supervisor issues a sheet named “Piping Fitting up Requirement/Check Sheet” which specifies the allocation of tasks and pipes, and hands it to fit-up workers.
- (2) Preparation: The fit-up workers check the sheet, and confirm drawings related to their task and pipes to work on. This process enables workers to get a picture of their goal and determine detailed procedures to achieve it.
- (3) Checking inside Pipe: The workers look inside the pipe to ensure that there is no foreign object, and then turn on a mobile PC and a digital camera to record it.
- (4) Performing the fit-up work: The workers perform piping fitting up, following the procedure prescribed on the sheet.
- (5) Filling the Fit-up Requirement/Check Sheet: The workers make sure that their work was conducted according to the procedures and fill out the sheet as evidence that they completed the work as instructed.

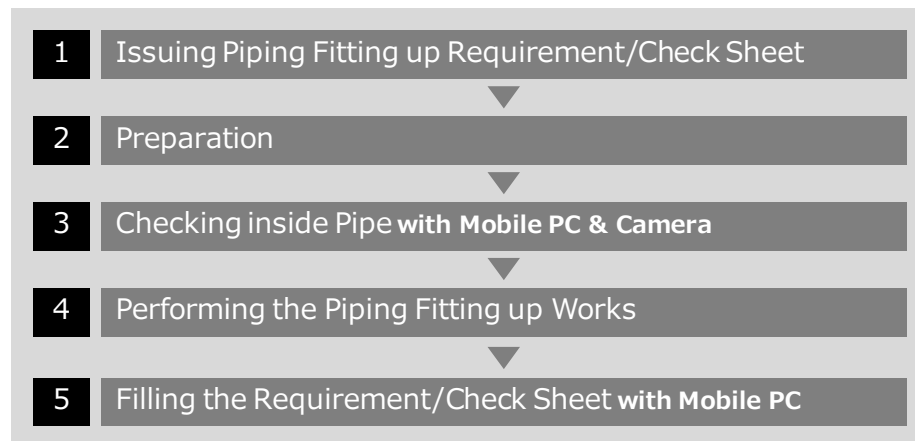


Figure 1: Prescribed Work Flow of Piping Fitting up

Step (3) and (5) had been handled with paper, but an electric system was introduced in which data can be input from mobile PC. The purpose was to improve the efficiency of searching their work records and after performing their task. However, this system was not used as it was intended. Therefore, a deep analysis was required to identify why the mobile PC was not used as intended, what adverse effects were produced at the site, and how the workers would be encouraged to use it.

3.3. Field Observation Methods

Each round of research was conducted over two to three days and involved three sets of interviews and observations at different times of the day. As research progresses, if it is necessary, the scope of research should be expanded to other relevant work in order to obtain an overall picture of work practices. At first, the research focused on the step (1), (3), and (5) in which the system was directly used, but the scope was expanded to (2) and (4) as well to clarify how these steps were related to other tasks.

During field observations, the ethnographers wore the same work clothes and used the same equipment as the on-site workers. This clearly differentiated them from visiting customers or administrators, and helped establish friendly relations with the workers (see Figure 2).



Figure2: Observation at Power Plant Manufacturing and Construction Sites

3.4. Analysis Procedure

In addition to the problems and concerns expressed by the workers, the observations and interviews also collected information about informal practice being used to improve the efficiency and quality of work at the site. Rather than dealing with problems and concerns individually, the data analysis was able to uncover the underlying problems within the organization by taking a broad perspective that considered how these issues were interrelated.

4. Results

The research identified why the system was not used and how adverse effects were produced at the site. The following sections describe essential findings of the research. In short, four main gaps between the system and workers' practices were found: (1) physical limitations (2) preference of paper over PC, and (3) difficulty of using a camera. These factors caused (4) an additional task to transcribe data from paper to PC. Besides, it was found that checking drawings with paper before work was a time-consuming task. These findings implied that the system which was supposed to help management provided little values to the workers, and functions that they really need were not provided.

4.1. Physical Limitations

Under the following conditions of the worksite, the workers had to perform their tasks in an unstable position (see Figure 3). This made it hard for them to bring and use a mobile PC in comfort.

- **Narrowness**
Huge pipes were placed near walls and there were small spaces which only one person can go through between them. Even under such a condition, a pipe should be held by two or three people, so the workers had to secure their safety space while watching carefully to avoid the pipe from scratching something around it.
- **Darkness**

The workers needed to use a penlight to watch and check dark places, such as the one overshadowed by a pipe or under a foothold, so they always brought a penlight with them.

- **Overhead obstacles**
The height from the floor to the foothold was very low, so the workers had to take care not to hit their head to any obstacles when doing a task under the foothold. It seemed that they actually hit their head very often, so their helmets had many scratches. Also, there were some places where the workers were not able to stand up, so they had to perform their tasks and move back and forth while sitting or squatting down.
- **Poor Footing**
Pipes and plates to build footholds were placed on the floor, and it seemed that this might cause the workers to stumble on the uneven surface. Besides, the workers sometimes had to use a ladder and stretch their arms to perform a task in the upper space, which should be unstable for them.



Figure 3: Examples of Physical Limitations

4.2. Preference of Paper over PC

The workers liked using a paper better than a PC, because paper would not be broken while PC could be broken easily. In addition, paper is relatively thinner and lighter than PC. Therefore, the workers preferably used a paper to record the results of their tasks, even though they understood the intentions and advantages of using a PC. Their comments were as follows.

“Writing on a paper is easier than using a PC. Besides, it won’t be broken even if I accidentally drop it.”

“Because I always care about the expensive PC while bringing it, I won’t be able to concentrate on my task.”

“If I break my PC or it does not work properly, it will take time to be fixed and I will waste my whole day.”

“I don’t get used to the PC. I don’t even have one at home.”

“Bringing a PC to the worksite means working with huge money.”

4.3. Difficulty of Using a Camera

Two types of cameras were provided to the workers to record inside of pipes to prove that no foreign object was there before performing piping fitting up work (see Figure 4). One was a camera connected with a mobile PC and the other was Bluetooth camera. Some workers were satisfied with the cameras because both of them were small enough to use in a narrow space. With respect to the usefulness, however, they pointed out a few problems as follows.

- The workers hardly adjust focus of the camera. *“I don’t know how to do it, so I get close to the object to get a sharp focus. But sometimes I cannot get close enough and miss the point. In such a case, I have no choice but to take an out-of-focus picture.”*

- Flash light is not equipped with the web camera. *“I have to hold the mobile PC with my left hand and the web camera with my right hand. Then I have to ask somebody to have a flashlight.”*



Figure 4: Using a Camera with a mobile PC

4.4. An Additional Task to Transcribe Data from Paper to PC

While the piping fitting up workers understood the purposes and advantages of using a mobile PC, they were not able to make the best use of it to let them focus on the fit-up work itself. Thus they had to use a pen and a paper just as before. This caused a new task for supervisors to gather papers from the workers and input the data with PC after they went back to their office. Besides that, however, supervisors had high priority tasks such as solving problems among subcontractors, so they had to have younger supervisors to do it instead or assign a person to input the data all day long. This data transcribing work increased their workload, and might result in making some mistakes.

4.5. Difficulty of Searching Drawings and Picturing Completed Pipes from Them

Some piping fitting up workers carried a case with folded drawings to pick up the right one from it for their work. And then, they had to find out necessary information and picture completed pipes from the drawings in their mind. However, it was observed that they could not find quickly which one to use, because the drawings were too many and too wide (see Figure 5). While paper was preferred to IT systems in some cases as mentioned above, it was not sufficient when the size and volume were huge. Moreover, because the drawings on a paper showed only 2D images, referring to the drawings of ordered pipes and imagining what the completed pipes would look like were difficult. Therefore, the workers brought the printouts of 3D CAD (computer-aided design) with them as a complement. However, this approach seemed insufficient because the printouts provided only a fixed point of view. Conversely, this implied that there was an opportunity to facilitate the use of the mobile PC if such burdens could be reduced and the IT system could be improved.

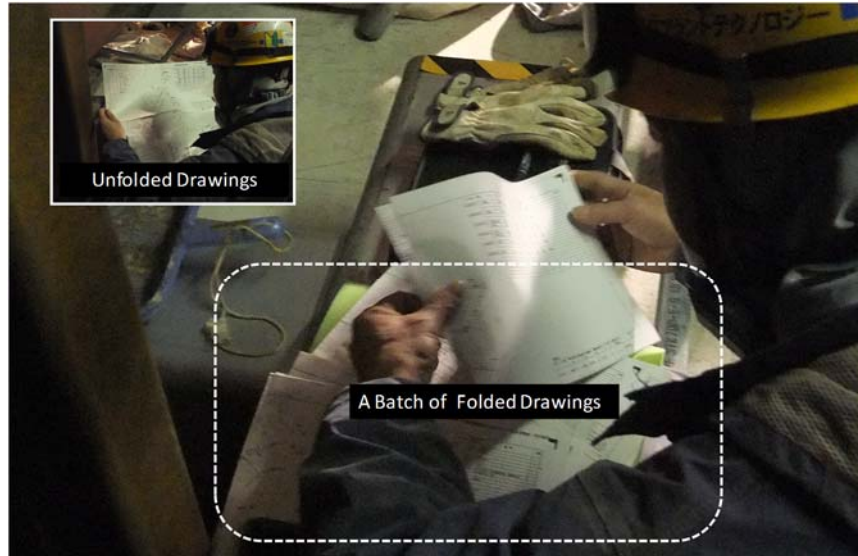


Figure 5: A Batch of Drawings and Their Unfolded Size

5. Ideas for Improvements

Drawing on the results of the ethnographic research, the scope of the improvement has been broadened to include the operation of the power plant construction management system rather than just the user interface of the system. For the piping fitting up work, an idealized operation such as how the site workers would like to undertake the tasks was drawn as Figure 6, considering the issues described in the previous section. The horizontal axis shows work processes involved in piping fitting up, and the vertical axis shows workers involved in these processes. The figure indicates the importance workers' place on each process. This chart allowed us to share the demands of the piping fitting up workers with stakeholders as below, and to find effective solutions for improvement from the perspective of the on-site workers.

- The piping fitting up workers see their mission as being to perform the fit-up work accurately, in accordance with the instructions, and on time.
- They want to complete preliminary preparations as quickly as possible, and without complications, so that they can focus their time on the actual fit-up work.

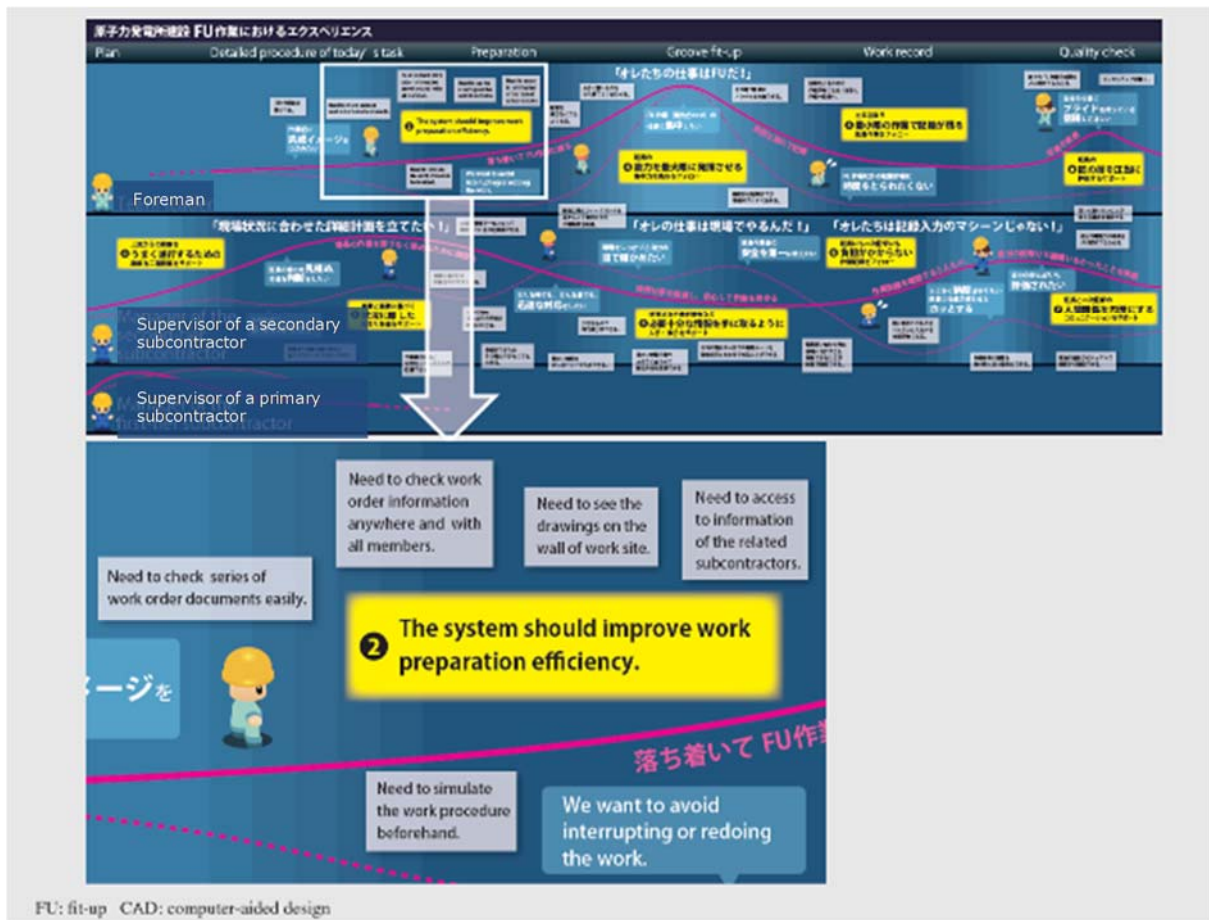


Figure 6: Work Practices as Seen from Viewpoint of Site Workers ("Experience Table")

For example, with respect to the 4.5, the workers' tacit needs were identified as "being able to pick up necessary information such as drawings as quickly as possible" and "being able to imagine the completed pipes from the drawings intuitively." Therefore, the following ideas were developed for the workers to obtain information easily and imagine the completed pipes clearly to perform piping fitting up at their worksite. The outline of the developed ideas based on this analysis is as follows.

(1) Tablet with a Case

To overcome the physical limitations, tablet devices which were lighter and smaller than the existing mobile PC were introduced, as well as cases to cover the devices. It is expected that this will make it easier for workers to carry and use the device at their worksite.

(2) 3D Layout and Construction Information Explorer

To let workers experience the superiority of IT system and motivate them to carry the device, 3D Layout and Construction Information Explorer was introduced. This function makes it unnecessary for workers to go back to their office to carry a large amount of drawings, and enables to reduce the risks of picking up out-of-date drawings mistakenly. It is expected that knowing these advantages will encourage workers to use the recording function as well.

These ideas for improvements were reflected to the system and introduced on the site as a trial use. It was found through interviews that the workers quite appreciated this system. They understood these advantages and gave us positive comments: "This is closer to the ideal system that we would like to use." "This 3D view allows us to check critical information for conducting construction work in physically tough environment. We can do it easily and quickly." "This carrying case is great because we do not need to use our hands to carry." Moreover, they made a

few requests such as "I want to jot down notes with this mobile device." This is indeed a positive behavioral change, because they did not make such a constructive request before these activities. This can be interpreted that they were motivated to use this system because they were convinced that it would be helpful for their work.

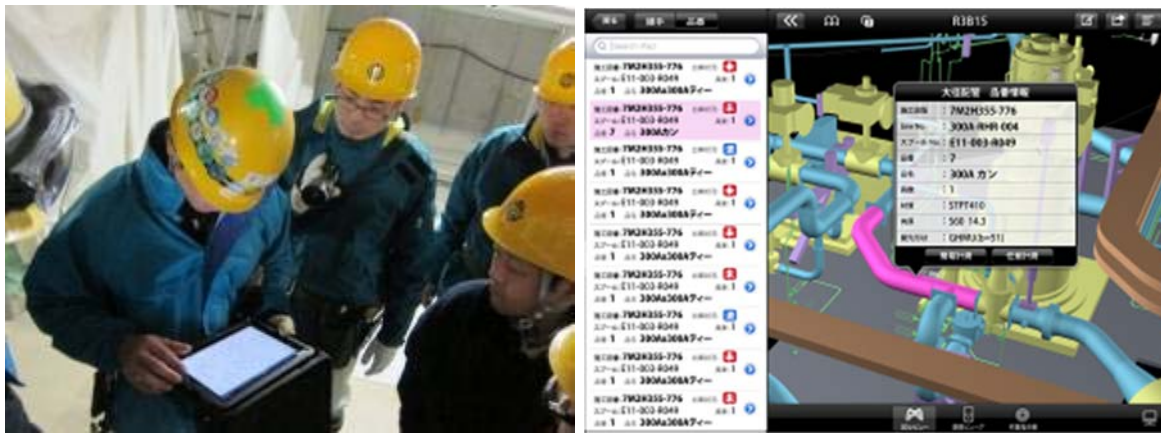


Figure 7: Examples of Ideas for Improvements

6. Conclusion

This article has described a case study of plant construction systems in which underlying problems and latent needs were identified through in-depth field observation. Not just fixing problems, but also providing functions immediately useful for workers increased the values of the system. In doing so, the system has been increasingly used by workers at their own initiative to improve the efficiency of their work.

This article has provided detailed process of ethnographic research as well as concrete examples of findings and ideas for improvement. Ethnographic research has often been used for consumer products, and its use has also expanded in recent years to cover the development of systems. Nevertheless, no similar articles have been published that touched upon such details of how underlying problems and latent needs were identified in complex working environment.

The case studies mentioned in this article are only a part of our efforts in improving the plant construction management system. Hitachi will continue enhancing quality, reliability and efficiency of plant construction activities through ethnographic research and continuous improvements based on the findings.

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Biography

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