IMPORTANCE OF STANDARD OPERATING PROCEDURE DOCUMENTS AND VISUALIZATION TO IMPLEMENT LEAN CONSTRUCTION

Yoshitaka Nakagawa[1]

ABSTRACT

In a previous paper (Nakagawa 2004), the author emphasized that standard operating procedure documents (SOPD) are important for implementing lean construction. This paper explains the need for SOPD, the conditions required of SOPD, and the factors that hamper the introduction of standard operating procedures at construction sites. The paper then explains how visualization is effective for introducing standard operating procedures at construction sites and achieving objectives in scheduling, quality, costs, and safety. Specifically, visualization in construction sites is discussed by considering the difference between manufacturing factories and construction sites. Finally, the paper explains visualization procedures, suggests that a PDCA circle using visualization and SOPD are essential for motivating kaizen (improvement). It also suggests that a strong commitment by top management is required to prevent stereotyped work.

KEY WORDS

Toyota Production System, Standard operating procedures document, Visualization, PDCA, Kaizen (improvement).

INTRODUCTION

The author emphasized in IGCL 12 (Nakagawa 2004) that standard operating procedure documents (SOPD) are important for implementing lean construction. The introduction of SOPD and the visualization of standard operating procedures (SOP) in the manufacturing industry are discussed in various papers, including references (Japan Society for Production Management 1996, Hirano 2001 and Moser et al. 2003). Moser et al. describe the effectiveness of visualizing standard operating procedures in the construction industry. The results of these studies show that the objectives of construction projects can be better achieved by integrating SOPD and visualization.

This paper describes 'Importance of standard operating procedure documents and visualization to implement lean construction' .The author explains the need for SOPD, the conditions required of SOPD, the factors that hamper the introduction of SOP at construction sites, and explains how visualization is effective for introducing SOP at construction sites. Specifically, visualization in construction sites is discussed by considering the difference between manufacturing factories and actual construction sites. Finally, the paper explains visualization procedures, suggests that a PDCA circle using visualization and SOPD are essential for motivating kaizen (improvement).

WHY ARE STANDARD OPERATING PROCEDURE DOCUMENTS (SOPD) NECESSARY?

THE IMPORTANCE OF SOPD

The author suggested in a previous paper (Nakagawa 2004) that the target duration for repetitive activities in a project can be achieved by preparing SOPD and familiarizing the workers in advance with the procedures in the documents. Carefully prepared SOPD based on experience are essential for achieving the target duration, quality etc. These SOPD should contain the following content:

1 Dr. Professor, Department of Civil and Environmental Engineering, Engineering Division, Toyo University

- Standard operation procedures that are designed to reduce waste in scheduling, quality, cost, safety- and environment-related activities, etc.
- Standard operation procedures that allow high levels of performance to be constantly achieved .In the construction industry, workers frequently change from one project site to another before becoming familiar with appropriate methods, resulting in repetition of a low level of performance. Standard procedures can prevent this tendency.
- Standard operation procedures that are designed to motivate improvement.

NECESSARY REQUIREMENTS FOR SOPD

Standard operation procedures must satisfy the following requirements.

- Provides the steps and details necessary to construct with minimum waste including construction methods, sequence, duration of each activity, priority on safety and quality, necessary parts and material inventory, etc:
- Uses worker-friendly, easy-to-understand language with simple statements and terms: and
- Content can be easily revised.

FACTORS THAT HAMPER STANDARD OPERATING PROCEDURES

The construction industry lags behind the manufacturing industry in terms of introducing standard operating procedures. In the construction industry, the rules and methods of performing common activities usually vary from project to project and worker to worker, resulting in fluctuating productivity. The reasons for this tendency are as follows:

- Although construction projects have many common activities, the details often change due to the unique natural conditions and technical specifications at each site:
- Compared with the manufacturing industry, the construction industry has few repetitive tasks: and
- In the construction industry, workers frequently change from one project site to another, making it difficult to familiarize them with standard operating procedures.

Although the above problems exist, lean construction depends upon familiarizing workers with SOPD.

EFFECTIVENESS OF VISUALIZATION

An SOPD describes the appropriate sequences and objectives for each activity such as excavation, formwork and scaffolding, etc. However, it does not cover the overall objective such as schedule and quality of the project and other related activities. As an example, Figure 1 describes the construction of a spread footing and pier for a bridge. This construction involves excavation, scaffolding, formwork, rebar arrangement work, pouring concrete, and other activities. The SOPD vary from activity to activity and different workers are generally employed for each activity. Since the workers perform only their allocated activity, they tend to become indifferent to the schedule and quality of the other activities and can unintentionally hamper progress in those other

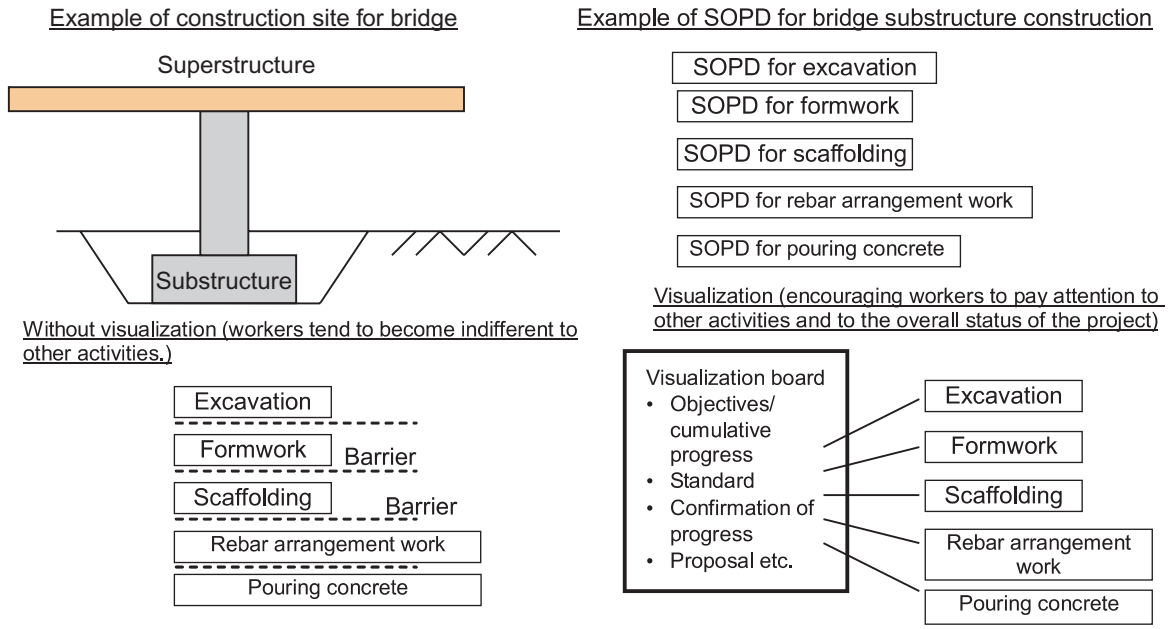


Figure 1: Example of standard operating procedures and visualization at a construction site

activities, which creates waste. This problem can be prevented by visualization.

Reducing waste by clearly indicating objectives and cumulative progress

When visualization is not implemented, workers tend to become indifferent to other activities. This creates waste, particularly in projects with a large number of activities and crews. Visualizing the objectives, progress, and minimum requirements for safety, quality, and environmental control can encourage workers to pay attention to other activities and the overall progress of the project, thus reducing waste. The benefit of visualization is more obvious in large scale projects.

Improving motivation

The level of understanding of the contents of SOPD varies from worker to worker. Visualization allows objectives to be shared by all workers, encourages communication, and improves motivation. The following are examples of the benefits of visualization.

- Displaying objectives and cumulative progress stimulates the workers' motivation:
- By displaying the successful results of *kaizen* (improvement) activities that were proposed by workers, the project management is clearly acknowledging the workers' contributions, which motivates them to make further improvements: and
- Displaying *kaizen* proposals and safety slogans created by workers and workers' groups encourages positive competition among them and further enhances their motivation to make improvements.

DIFFERENCES IN VISUALIZATION BETWEEN FACTORIES AND CONSTRUCTION SITES

Table 1 shows an example of visualization in factories. This example was extracted from Hirano (2001) and includes the 5S's (*seiri* (keep orderly), *seiton* (keep tidy), *seiso* (clean up), *seiketsu* (keep clean) and *shitsuke* (practice good manners)), schedule control, quality control, safety control, and motivation improvement.

As described above, the conditions at construction sites differ from those in factories, and the visualization tools used in factories cannot be applied at construction sites in the same manner. However, as Table 1 shows, many tools can be effectively used at construction sites (items described as "already applied" in the far right column in Table 1). In Japan, visualization tools for safety control are widely used construction sites, but tools such as the *andon* system and the multi-skilled worker deployment plan (items described as "not possible" in the far right column in Table 1) are very difficult to use at construction sites because of the following reasons:

- The *andon* system uses fixed displays to notify workers of problems. All workers must be able to immediately recognize the visual or aural alarms activated by the system. This can be done in factories, but construction sites are often very large, with many different activities taking place simultaneously at many different locations. This makes it difficult to notify all workers of problems using factory type visualization systems;
- Standard operating procedure cards are a very effective tool for familiarizing workers with the sequence of routine tasks that take place at fixed locations. At construction sites, however, the workers performing an activity do not stay in one location, and several activities often take place simultaneously at one location. This makes it difficult to use standard operating procedure cards;
- A multi-skilled worker deployment plan trains factory workers so that they are able to perform several tasks. In the manufacturing industry, workers are generally on a payroll. Construction workers, however, are usually employed on a daily basis by subcontractors, making it difficult for main contractors to train workers in many skills; and
- Error prevention boards are designed prevent the recurrence of errors by displaying examples of the errors and problems caused by each crew. In the manufacturing industry, crews are deployed at fixed locations and they usually perform repetitive tasks, making it relatively easy to determine the causes of errors and problems. At construction sites, however, the crews move from one location to another as the project proceeds, and there are relatively few repetitive tasks. This makes it difficult to determine the causes of the errors and problems.

SEQUENCE OF VISUALIZATION

The sequence of visualization taking into consideration the characteristics of construction sites is described below.

REQUIREMENTS

As shown in Table 1, the construction industry in Japan employs enough visualization for safety purposes, but not enough in other areas where

visualization tools take time to produce and offer questionable benefits. The following factors ensure effective visualization:

1. Scope

- Engage the entire construction site and all crews in the project.

2. Objectives

- Establish easy-to-understand requirements (schedule, safety, quality, environment, etc.) and ways to prevent errors and mistakes;
- Establish systems that allow workers to recognize problems (schedule delays, etc.) and take the necessary actions in a timely manner;
- Improve motivation; and
- Establish systems that encourage communication among workers.

3. Keypoints

- Clearly indicate the important points of the SOPD and the minimum requirements. Organize the content so that workers can easily identify problems;
- Prepare easy-to-understand materials (e.g. graphs);
- Prepare easy-to-produce and easy-to-display materials;
- Produce separate visualization materials for common-use areas and each activity area; and
- Display the board for common-use areas used by all workers (e.g. morning assembly area, rest areas, etc.)
- Displayed items: safety operation cycle diagram, schedule for transporting equipment and materials in and out of the site (item names, time, vehicle, crane, elevator, etc.), number of workers employed by each subcontractor, details of the day's activities and the progress of each activity, plan views of the areas where activities will take place,

Table 1: Visualization in factories and application to construction site

Category	Item	Detail	Application to construction sites
5S	Safe passage	Separation of safe passages, working areas, and storage areas by white (red) lines.	Already applied
	Keeping material storage areas in order	Takes into consideration the production sequence	Possible
	5S status display board	Displaying results of 5S status inspections	Possible
Schedule control	Andon system	Tool for announcing malfunctions and problems	Not possible
	Kanban system	Tool for achieving just-in-time production	Possible
	Standard operating procedure card	Card showing sequence of operation	Not possible
	Production control board	Displays schedule and actual production	Possible
	Multi-skilled worker deployment plan	Displays manufacturing process capability of each worker, and schedule for developing multi-skilled workers	Not possible
Quality control	Error prevention board	Displays causes and examples of errors to prevent recurrences	Not possible
	Quality display board	Displays required quality	Possible
	Quality control board	Displays status of quality conformance	Possible
Safety control	Dangerous place display	Displays dangerous locations and category of danger	Already applied
	Qualified worker display	Displays workers qualified to perform certain activities	Already applied
	Safety slogan display	Displays safety slogans created by workers	Already applied
Motivation improvement	Kaizen (improvement) proposal competition display	Displays number of good kaizen proposals made by each worker group	Possible
	Kaizen activity result display	Displays status before and after kaizen activities, and their effects	Possible

Table 2: Example of activity schedule and progress control board

No	Crew	Number of crew members	Work area and activity	Target / actual progress	Precautions	Work area and activity	Target / actual progress	Precautions
1	A	10	Formwork for 5F columns and walls	3T/2T		Same as at left	Same as at left	
2	B	8	Scaffolding for 6F floor slab	40 m2 /40m2		Same as at left	Same as at left	
3	C	4	Installation of prefabricated rebars for 5F beams	2T/3T		Same as at left	Same as at left	

weekly and monthly schedules, the daily arrangement of workers in each activity area, weekly 5S status board, etc.
- Display boards for each activity area, including the precautions to be taken for each activity.

DETAILS OF VISUALIZATION METHODS FOR CONSTRUCTION SITES

4. Schedule control

The visualization tools applicable to schedule control at construction sites are the production control board, *kanban* system, and just-in-time (JIT) control board. These tools are described below:

- The production control board displays the comparison of schedule and performance to show production speed. Specifically, it displays the progress target(for the morning and afternoon hours, as well as for the next working day, week, and month) and the actual progress of each crew. Table 2 shows an example of an activity schedule and progress control board, a type of production control board. The foreman fills in the actual progress at designated times. By producing a graph comparing the schedule with the actual progress, information on the daily production rate of each activity can be provided to all workers, thus increasing their motivation.
- The *kanban* system is a tool for achieving JIT production. In this system, parts and members are fitted with a *kanban* showing important information such as the specifications, delivery destination, and delivery time.
- The example of JIT control board in Table 3 provides schedule information for the transport of materials and equipment into and out of the construction site. The board also lists the quantities of materials, locations where they will be used and the time when they will be transported. The board is particularly useful in areas where there is no room to temporarily store the materials.

5. Quality control

In quality control, it is important to inform all workers of quality requirements and clearly indicate by whom and when quality is to be checked.

- Quality display board
  A quality display board is very effective for providing information on quality criteria, especially when the criteria cannot be expressed numerically. Figure 2 is an example of a quality display board that shows the requirements for treating concrete joint surfaces and cleaning rebar surfaces.
- Quality control board
  A quality control board is very effective for providing information about who performed the quality and the after-work cleanup

Table 3: Example of JIT control board

	AM, dd/mm	PM, dd/mm	AM, dd/mm	PM, dd/mm
Entry of truck	10:00 XX 5T	4:15 YY 50 pieces	10:00 XX 5T	4:15 YY 50 pieces
Exit of truck	11:00 YY 3T		11:00 YX 3T	
Use of crane	Rebar arrangement (4F east)	Formwork (4F east)	Rebar arrangement (4F west)	Formwork (4F west)
Use of elevator	10:00 – 11:00 Equipment installation (3F east)			10:00 – 11:00 Equipment installation (3F west)

Table 4: Example of quality control board for interior work

Quality control board for interior work (Room 203)							
Item	Date	Cleanup	Quality	Item	Date	Cleanup	Quality
Installation of sashes				Entrance floor finishing and tile placement			
Filling in of voids around sash frames				Installation of plaster boards			
Repair of ceiling and wall				Creation of openings in plaster boards			
Installation of window architraves				Installation of kitchen equipment			
Glass installation				Placement of finishing cloth			
Installation of under-floor pipes				Connection of water supply and discharge pipes			

Note: a quality check and cleanup are performed before proceeding to the next activity. The form is signed by person who performed the quality check and cleanup inspection.

checks, and when they were performed, thereby eliminating the need to redo the work. Figure 3 shows an example of a quality control board for interior work.

6. Cost control

Since costs are dependent on the quantity of the materials and equipment and the number of workers, they can be estimated by comparing the assumed and actual quantities as shown in Table 2.

7. Safety and health management

Safety and health management includes displaying the locations of dangerous areas, the names of workers required to perform special activities, and safety slogans. Safety and health management are routinely practiced in the construction industry in Japan under the guidance of the Labor Standards Supervision Office.

8. Environmental management

- Environmental management includes displaying environmental criteria (e.g. standards for waste water discharged from the site) and environmental management records.
- Waste management includes displaying disposal standards (e.g. separation of paper, plastic, wood, metal, etc.). A chart comparing the actual waste volume with the target volume can be used to motivate workers to reduce waste.

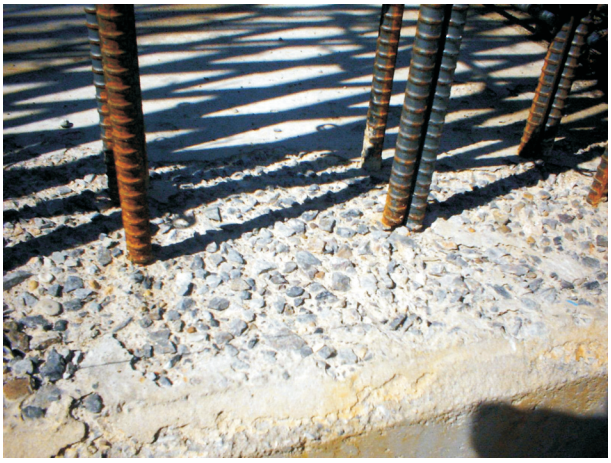
Good quality example	Poor quality example
	

Figure 2: Example of quality display board (Treating concrete joint surfaces and cleaning rebar surfaces)

Table 5: Example of 5S status display board

Item	Location	Activity/action	Result of assessment		
			Monday	Tuesday	Wednesday
Seiri	2F	Keeping materials in tidy order	Good	Fair	
Seiton	3F	Storing materials according to the order of their retrieval	Good	Good	
Seiketsu	2F	Proper arrangement of trash bins	Good	Fair	
Seiso	5F	Removal of trash	Poor	Good	
Shitsuke	Rest area		Fair	Good	

9. 5S

- Materials must be stored in an organized manner that takes into account the order and ease of retrieval for subsequent activities. It is very effective to produce and display a diagram showing the storage location of each material.
- 5S status display board: *seiri*, *seiton*, *seiso*, *seiketsu*, and *shitsuke* (5S) are essential elements for lean construction. By displaying a board similar to the one shown in Table 5, the status of the 5S elements assessed by the designated person can be known by all workers, thereby enhancing their motivation to further improve the site conditions.

10. Enhancing motivation:

- Display the names of responsible persons
  Displaying the names of the people responsible for each work area and material storage area motivates workers to improve their workmanship and enhances 5S activities.
- Display safety and health slogans at regular intervals
  Displaying slogans at the site and rewarding the workers who created them motivates the workers to improve the quality of their work.
- Encourage *kaizen* proposal competition among crews
  Rating the number and content of *kaizen* (improvement) proposals made by the crews and displaying them creates positive competition among the workers and encourages them to develop better proposals.
- Display *kaizen* activity results
  Displaying a board similar to the one shown in Figure 3 enhances worker motivation. The board lists the names of persons who have made *kaizen* proposals, the differences between 'before' and 'after' the proposed *kaizen* measures are implemented, as well as the costs and time saved by the proposals.

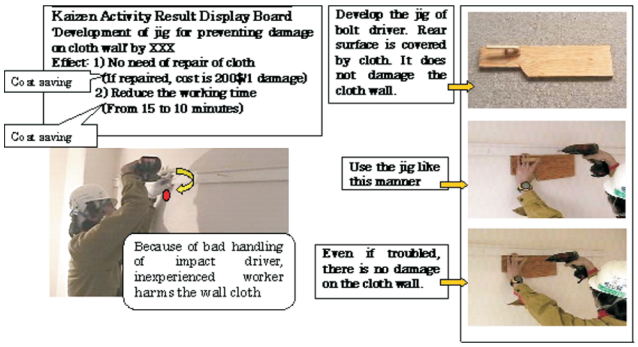


Figure 3: *kaizen* activity result display board

LEAN CONSTRUCTION BY UTILIZING SOPD AND VISUALIZATION

Figure 4 shows the steps for using SOPD and visualization to educate workers at construction sites about lean construction.

DOCUMENT PROBLEMS AND DEVELOP NEW *KAIZEN* MEASURES

The progress and current quality status are first identified by investigating the methods used for each activity and measuring the time (to the second) needed for each activity. Video-taping is effective for this purpose. Problems that result in waste are then identified by analyzing the duration of each activity. This data is then used to develop work procedures (*kaizen* proposals) that reduce waste.

IMPLEMENT *KAIZEN* PROPOSALS

A hypothetical work procedure is first produced using data from previous construction projects. The procedure (including equipment and devices) is then modified using the *kaizen* proposals. A model group tests this modified procedure, and the duration is measured to the second. Finally, the test results are used to produce an SOPD, which is given to every crew at the site. Visualization tools are used in combination with the SOPD.

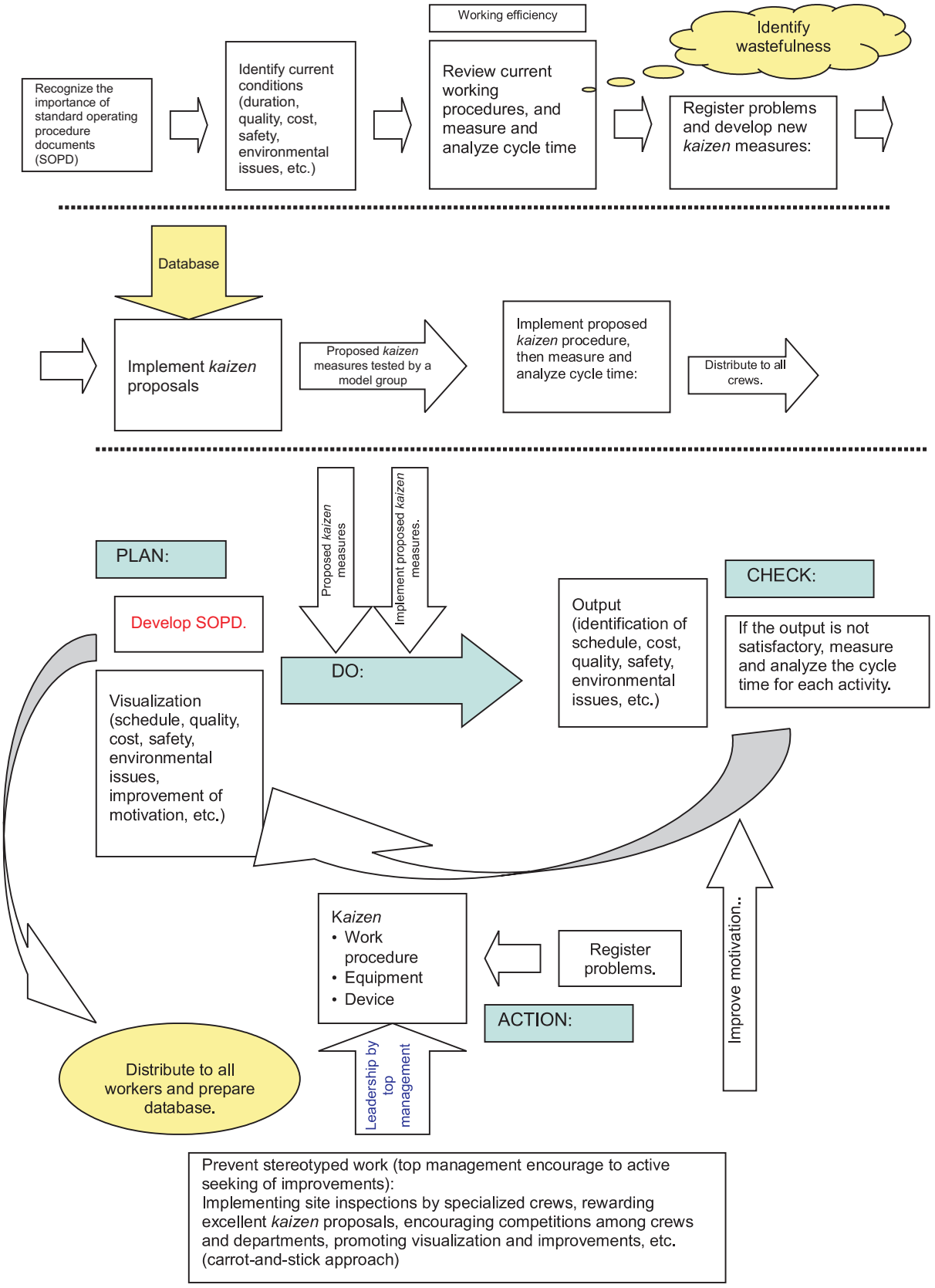


Figure 4: PDCA cycle using SOPD and visualization tools

PLAN, DO, CHECK

In combination with the visualization tools, the SOPD produced by the above steps is applied to actual construction activities on the site. At the same time, *kaizen* proposals are continuously solicited from workers, with the best ones immediately incorporated into the standard operating procedure. If the target objectives for schedule, cost, and quality are not achieved, the duration of each activity is again measured and analyzed.

ACT

Problems identified in the above analysis are noted and resolved by modifying the work procedures (including equipment and devices).

PREVENT STEREOTYPED WORK (ENCOURAGE TOP MANAGEMENT TO ACTIVELY SEEK IMPROVEMENTS)

PDCA circles tend to become stereotyped. To prevent this, implement site inspections by specialized crews, reward excellent *kaizen* proposals, encourage competition among crews and departments, and promote visualization and improvements. These require the site management staff as well as the top management of the contractors to actively seek improvements.

CONCLUSIONS

This paper is focusing on SOPD and visualization in construction sites to implement lean construction. From the study the author point out the following conclusions:

- SOPD must be used together with visualization tools.
- Visualization is effective for notifying construction workers of target levels and standards of duration, quality, safety, etc., and for motivating them.
- Many of the visualization tools used in the manufacturing industry can be applied to construction sites.
- Visualization tools and measures must comply with site conditions and be continuously revised and modified as needed.

ACKNOWLEDGEMENTS

I wish to thank Fukuda Corporation that has made this research possible.

REFERENCES

Hirano, H. (2001): "Management Using the *kanban* System and Visualization Tools," Nikkan Kogyo Shimbun, Ltd.

Japan Society for Production Management (1996): "TOYOTA Production System," Nikkan Kogyo Shimbun, Ltd.

Moser, Santos, A (2003): "Exploring the Role of Visual Controls on Mobile Cell Manufacturing: A Case Study on Drywall Technology"—IGCL 11, USA

Nakagawa, Y. (2004): "TOYOTA Production System Adopted in Building Construction in Japan"—IGCL 12, Denmark