USING THE KANBAN FOR CONSTRUCTION PRODUCTION AND SAFETY CONTROL

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ABSTRACT

The paper explores non-traditional applications of the Kanban. "Kanban" is the Japanese word for "visual cards" and is a Lean tool developed in the automotive industry for JIT production. The Kanban acts as a work order without which work should not start, and has also been used as a material process flow technique for the pull replenishment logic system. The Kanban is usually used in the construction material procurement process by organizing orders, acting as a visual tool for the improvement of communication among all stakeholders, and insuring that the right amount of the right item is delivered at the right time. This paper seeks to promote the use of the Kanban as a work order for the construction production process, and as a construction process control tool. There are two types of Kanban described in this paper: the ordering Kanban, and the receipt Kanban. The Kanban is also useful as safety control tool because safety information is included on each Kanban. Due to the Kanban's ability to increase communication, and to decrease the number of accidents, this paper highlights one of the most important findings of these case studies: the use of the Kanban in construction production and safety control.

KEY WORDS

Kanban, production control, safety control, and case study.

INTRODUCTION

Proper production management and safety control account for substantial portions of project cost and time.

The Lean tool developed for just-in-time (JIT) production in the automotive industry is the "Kanban", which is the Japanese word for "visual cards". The Kanban is used as a material process flow technique for the pull replenishment logic system. The JIT approach to control manufacturing systems with the Kanban has received a lot of attention in the last decade (Chase, 1973; Hall, 1983; Huang et al., 1983; Krajewski et al., 1987; Suzaki, 1987; Shingo, 1988). The idea of JIT technique reduces inventory and production cycle time, increase the speed of information exchanged, and improve productivity.

The Kanban usually organizes orders; work should not be started without the Kanban. The Kanban system efficiently controls repetitive manufacturing environments and offers simplicity. It is a visual tool for the improvement of communication among all stakeholders. To achieve the goal of a Lean production environment, the use of the Kanban technique has minimized the work-in-progress (WIP), and inventory costs. It insures that the right amount of an item is delivered at the right time (Chase, 1973).

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This paper explores the application of the Kanban for purposes that are different than from its current use, and seeks to initiate the use of the Kanban as a work order. The Kanban is usually used in the construction material procurement process (Arbulu et al., 2003). Here, however, the Kanban would be used as construction production process control tool, and as a safety control tool. A synchronization mechanism for Kanban-controlled production, and safety control systems, was developed in such a way as to yield feasible workflow reliability as well as improving safety conditions. Safety information was included on each Kanban to aid in safety control.

There are two types of Kanban utilized in this paper: the ordering Kanban, and the receipt Kanban. In the Kanban system, cards that contain information such as 1) job type, 2) quantity, types and number of labourers, 3) prerequisite and successive work, 4) materials, and 5) safety information become crucial in production and safety management. With the movement of the cards, information becomes tangible and easily understood. At each phase of construction process, the information about work ordered, work volume, start and finish dates, reasons for non-completion, and so on, can be easily obtained from the Kanban.

PRINCIPLES OF THE KANBAN SYSTEM IMPLEMENTATION

IMPLEMENTATION OF THE KANBAN SYSTEMS FOR WORK ORDERING

These are the main principles for the implementation of the Kanban systems in this paper (Hall, 1983; Ohno, 1988; Singh and Falkenburg, 1994). They have been modified for the construction work ordering process in this paper.

- Levelling of production (balancing the schedule); production control combined with the Last Planner System
- Avoiding complex information and hierarchical control systems on job sites; pull system
- Not starting work without an ordering Kanban
- Checking work progress with a receipt Kanban
- Not sending incomplete and defective work to the succeeding stages
- Providing safety instruction and previous accident files for relating work

FUNCTIONS OF THE KANBAN

The key objective of the Kanban system is to order work JIT to construction workstations, and to pass information on to the earlier stages regarding what work must be done and when to finish that work. Also, the safety information contained on each Kanban is specific to the type of work being ordered. Thus, a Kanban fulfils the following functions:

- Visibility: the work and safety information are combined together on the Kanban and move with those in charge of the work
- Production control: work should not be started without an ordering Kanban, because they indicate the time, quantity, and the types of work to be started. The Kanban are distributed by the controller in charge of the entire construction schedule.
- Progress monitoring: the number of the receipt Kanban actually measure the amount of work completed. Hence, the number of receipt Kanban, are compared

to the number of work orders completed. The controllers collect the receipt Kanban which are filled out by field engineers, including information about the type and amount of work completed. From this information, the controllers can make progress payment reports. The more receipt Kanban, the higher the amount of the payments. Collecting the Kanban is much simpler than checking the amount of work completed in person.

- Safety control: since certain types of work are prone to certain types of accidents, the information about over 1,300 accidents has been categorized by project and work type. They have been put into a reference book containing descriptions and photocopies of these accidents, each numbered, and including what, when, where, why, how they happened, and how to prevent future accidents of the same type. Appropriate references are automatically put on the Kanban for each task. Field engineers, before ordering work from the downstream workers, show or post this information on a board for them. Workers being shown actual cases are more likely to pay attention. Even if there have been no accidents in order to make continuous improvements, this information is updated quarterly. In this case study this information was used as a reminder to the field workers. If an accident happened in the field, the field engineer filled out the specific information on the receipt Kanban as a record

TYPES OF THE KANBAN

According to their functions, Kanban are classified into:

- *The Ordering Kanban* travels from an office work controller to a field engineer who is in charge of the work execution on the project site. This Kanban includes: the type of work, the identification number for the work, who is accountable, amount, location, start and end dates, resources (materials, equipment, and labour) needed, unsolved constraints[3], prerequisite and successive work, special orders for the work, and safety information (figure 1). An exact number of Kanban are printed out for each day, because of the need to track the daily Percent Planned Completion (PPC). Each manager has a daily Kanban mailbox. After the weekly work plan is set up, the Kanban are automatically issued and put into each manager’s daily mailbox by the controller.
- *The Receipt Kanban* is originally part of a set also including an ordering Kanban. Receipt Kanban travel from a field engineer to an office work controller. This Kanban includes information which is the same as on the ordering Kanban, plus a box to check for work-completed, a space for the actual date of work completion, and reasons for non-completion if work was not finished on time (figure 1). Kanban are used to calculate performance measurements for production process and progress payments directly because this Kanban includes the rate at which work is completed. The controller goes out into the field and checks progress, or asks field engineers about the work completed before using this. Field engineers fill out all the information about the work submitted on the Kanban, so all of the information can be shared among the project members transparently.
- *The Auxiliary Kanban* is used for additional work and backlogs. These Kanban are issued based on the weekly work plan, but there are cases when additional work must be ordered by an owner. Since no work may be started without a Kanban,

[3] Tasks containing constraints that that are likely solved by the beginning of start of work

and additional work or backlog is unplanned, this work still needs to be controlled, so it is issued an auxiliary Kanban and managed separately to measure performance.

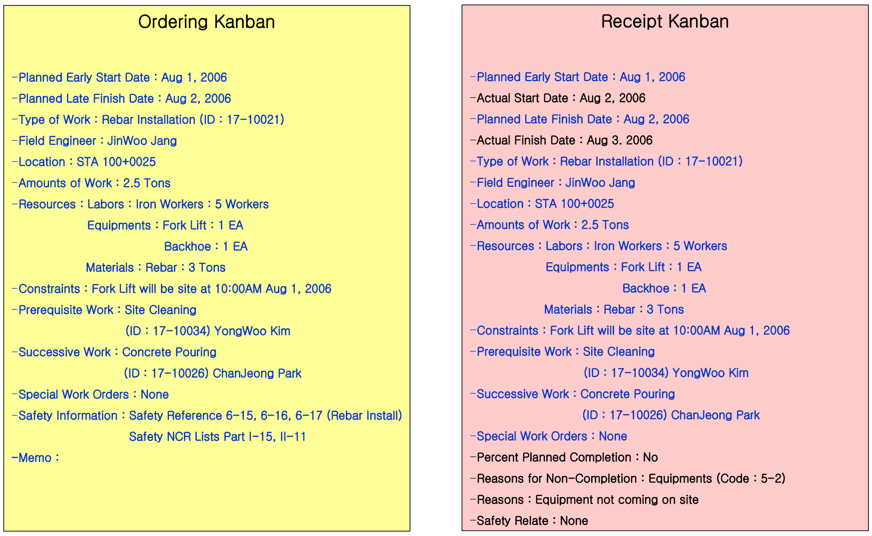

Figure 1: Types of Kanban Using in this Study

GENERAL DESCRIPTION OF KANBAN OPERATIONS

The Kanban is a control mechanism that links production activities and transmits demand information among the project members.

The information on the Kanban is based on the weekly work plan. Kanbans are issued daily, not weekly except for the auxiliary Kanban. The case study company organized itself into three departments: management, construction, and construction support. The field engineer worked in the construction department. All three departments planned together, however, all work was ordered by project controller (Last Planner) in the construction support department, so the Last Planner is not the same person as the field engineer.

Figure 2 shows the circulation of the information on the Kanban. The Kanban in these case studies plays an important role in the sharing of information, and controlling production flow and safety in the construction process. The general operational process is as follows:

- Step 1: Based on the six-week lookahead schedule, the weekly work plan is made by all project members (pull schedule). This step is identical to that of the Last Planner System.
- Step 2: Based on the weekly work schedule, all of the ordering and receipt Kanban are printed out for each day.
- Step 3: Safety instructions and references to previous accidents are added to the Kanban.
- Step 4: The Kanban are sorted by day and by project field engineer.
- Step 5: Each day, before work starts, the field engineers pick up the Kanban from their daily work order mailbox.
- Step 6: The field engineer orders the work to the downstream workers and shares safety information with the field workers.

- Step 7: The field engineer fills out work progress information on each receipt Kanban.
- Step 8: The field engineer tears the Kanban set, keeping the ordering Kanban for verification, and returning the receipt Kanban to the return mailbox.
- Step 9: The office work controller collects the receipt Kanban to check work progress and makes the progress payment reports based on the information from the Kanban.
- Step 10: The office work controller measures performance by checking PPC, reasons for non-completion and, the rate of accidents.

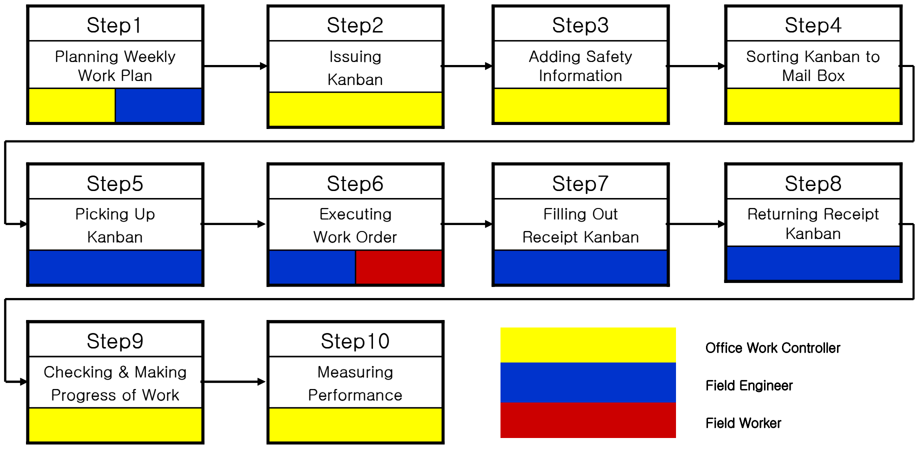

Figure 2: Circulation of work order information via the Kanban and Participants information.

The only way to initiate work is by Kanban. When the weekly work plan is made, the field engineer selects the work for the next week based on the six-week lookahead schedule. Most of the work is made-ready. Where it is not, the field engineer gets information about constraints and tries to solve these constraints before the start of work. This is in line with the guidelines of the Last Planner® System (LPS), which makes it possible to pull the work (withdrawing it) instead of pushing the work to the field engineers.

CASE STUDIES

These case studies explored non-traditional uses for Kanban, and sought to promote the use of Kanban as work orders. The three case studies focused on the use of the Kanban system for production and safety control in heavy civil construction projects.

The LPS is a screening process for activities or tasks which require resources unlikely to be available by the start date. The result is a strict sequence of releasable tasks. The role of Kanban in the LPS is as a directive that production units follow in exact order.

The Kanban system was used as part of LPS. The LPS had already been implemented in the case studies. One of the most critical reasons to implement the Kanban system was to improve workflow reliability, especially in the handoff of trade-work. Sometimes field engineers did not keep track of the plan that was made during the weekly planning meeting. Mostly, they finished the work planned within the week, but, did not follow the schedule, for example, doing work out of order, or not starting on time.

Another reason to implement Kanban was to improve the safety record of the case studies. The case study company had invested a lot of money in improving its safety record, but this effort only directly affected management, not the workers.

Table 1: Brief Descriptions of Case Studies

Case	Project Duration	Project Amount (USD)	Total Work Completion	Main Activity
A	7/2002~12/2007	42 Million	77%	Total Length(TL) 1820m Tunnel 738m, Station 75m
B	12/2004~12/2007	15 Million	58%	TL 1188m Tunnel 336m, Station 75m
C	12/2002~12/2007	28 Million	51%	TL 3824m Tunnel 738m, Station 150m

The three case studies were undertaken for six months. Before the start of the case studies, there were three training sessions for each project site by the authors for the implementation of the Kanban system. Included in the cases were subway projects carried out between April 2006 and September 2006. There were three types of schedules used in the case studies: the master, and six-week lookahead schedules, and the weekly work plan. In these case studies, the phase schedule was not used, because the general contractor released phase schedules based on flaw-free design to the company doing the pilot project.

During the six months case studies, PPC, CPI, rate of accidents, safety relate non-conformance reports (NCR) rate, and reasons for work non-completion were tracked to analyze the effectiveness of the implementation of the Kanban system. All of those indicators were tracked daily and reported weekly. In the weekly work meeting the project members provided their suggestions to the authors. The authors were provided weekly progress reports to screen, and then returned them with comments in order to monitor their progress.

IMPLEMENTATION FINDINGS

The PPC, CPI, rate of accidents, and the numbers of the safety-relate NCR were traced daily and reported weekly during the case studies. In all three projects, the authors have standardized the scope of tasks to create a work breakdown structure for data validation.

INTERVIEWS WITH PARTICIPANTS

During the three training sessions given by the authors, implementations of the Kanban and Last Planner Systems were discussed. Project members gave their opinions about using the Kanban system in their project sites. The weekly meetings were the most useful for soliciting the project members' opinions. All of project controllers mentioned that, when using the information from the Kanban, it was very easy to get to the source of the measurements of the project's performance. For example, it was easy to measure performance by tracing PPC, reasons for non-completion, and accident rates. However, some of field engineers mentioned that the increasing amount of paperwork was a hardship. Therefore, most of project controllers advocated using the Kanban system, and most of field engineers were against it. However, all project members agreed that Kanban system increased workflow reliability.

In Case B the project controller pointed out that issuing a Kanban for each task made field engineering more complicated. Field engineer who was charge of repetitive work held more than ten Kanban a day. They suggested issuing one Kanban for this kind of repetitive work. To simplify the system, they combined the WBS of the repetitive tasks, and issued a new ID. This improvement made the paperwork easier for both the office controller and field engineer, and decreased the number of Kanban issued.

The field workers mentioned that the Kanban system would probably decrease accidents. Previously, field engineers had just told downstream workers to be careful. However the accidents listed on the Kanban were real, relevant, and timely. Some project sites made a bulletin board and posted a field worker Kanban, which helped them to recognize elements of risk in the work site. It also helped them to understand the phase of the work, progress necessary, and the amount of their daily portion of work.

PERCENT PLANNED COMPLETION (PPC)

During the six-month case studies, the average number of tasks in each weekly work plan was 112. The weekly average and four-week moving average PPC were measured as shown in Figure 3 during the six months. The average PPC was 73%, ranging from 51% to 84%. There was a steady period of improvement Weeks 9 to 13 up to the level of 81%. A possible explanation for the increase is that the monitoring of PPC improved because the office controller (construction support department) and field engineer (construction department) reviewed the PPC and made possible work plan together. Also, continuous training sessions in the Kanban and LPS made this improvement possible.

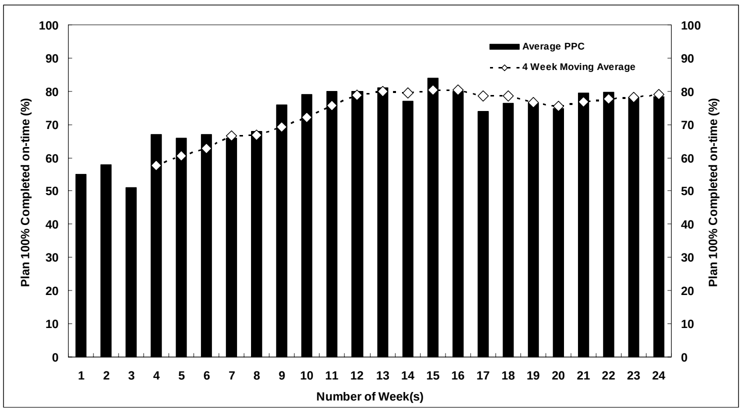

Figure 3: Average of Percent Plan Completion (PPC) and four-week moving average for three-case studies over a 24 week period.

THE NUMBER OF THE SAFETY-RELATED NON-CONFORMANCE REPORTS (NCR)

The general contractor has a weekly checklist of safety factors called the NCR. It is brought around the site to seek out potential safety hazards. In the three case studies the number of the NCR decreased steadily through the project. The general contractor pointed out that the average was 37 before adopting the Kanban system. The average number of the NCR decreased to ten after implementing the Kanban system.

SAFETY ACCIDENT RATES

Figure 4 shows the accident rate for six months before and after the implementation of the Kanban System. Sometimes, construction companies lost money because of accidents, but in these case studies, the definition of accident is purely human-related. Accident rates decreased 33% in the six-month period. Cases A and B had no accidents. Furthermore, during the case studies, there were no deaths, or workers losing bodily function due to injury. The company had had 384 accidents between 1981 and the beginning of the case studies and lost over 15 million dollars.[4] However, there were just thirteen accidents during the six months after the Kanban system was implemented. These accidents were not a major issue to the entire project process. During the case studies the Kanban system had made a visible contribution to reducing the rate of accident.

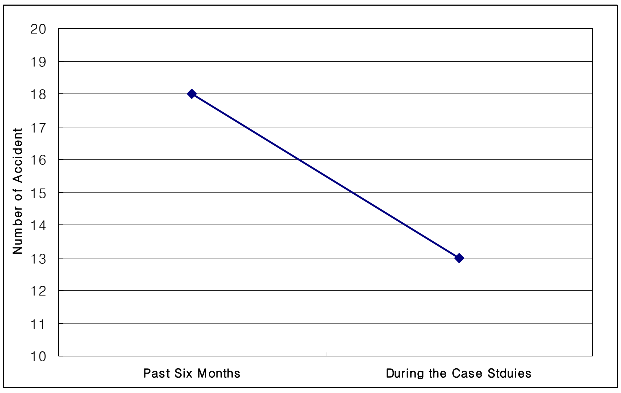

Figure 4: Accident rates for the three-case studies before and after the 24 week period.

COST REDUCTION

Under perfect circumstances, the amount budgeted should be exactly the right amount. Yet, planning in theory is very different than planning in practice because the budget has many influences, and is often not straight-forward. For example, it would seem that there would be a direct savings for tasks completed early. However, tasks are not discrete from others in the same project thus, a task completed early does not always translate into a net savings. Completing tasks on budget is further complicated by the fact that there is usually more than one stage of production involved in task planning. In these case studies, budgeting was further complicated by the fact that things did not always happen as planned.

In this project author tracked cost data to examine the effects of the Kanban system on costs. There is a possibility that if we had implemented our idea from the inception of the project then there might have been a different net loss or gain, but the implementation of our idea occurred in the middle, so it is hard to say how accurate the cost data is. The cost savings in the six month case studies were not significant. During the period, the Cost Performance Index and the Schedule Performance Index improved by 5% and 10% respectively.

[4] Source from case study Company's list of compensation for safety accidents relate. The compensations included compensatory and exemplary damages.

CONCLUSION AND POSSIBLE AREAS FOR FUTHER RESEARCH

CONCLUSION

This paper has presented a production and safety management strategy that uses the Kanban System in construction projects, and has highlighted the importance of implementing a process-driven Lean strategy across organizational boundaries. Kanbans were used as a production process control tool under the LPS. In this paper authors found that Kanban supported the LPS by clarifying the hand-off processes among trades, and improving the safety record. Based on the three case studies in this paper, the Kanban system improved:

- Visualization
- Informational transparency
- Communication among project members
- Accuracy in forecasting production work performance
- The rate of accidents
- The safety-related number of non-conformance reports

The key to improving production performance is to consider such factors as the size of an order, the standardization of the work breakdown structure in order to shape a construction environment with more uniform work flows and flexibility. The Kanban system is valuable for monitoring construction performance.

The problem of production levelling through scheduling is crucial in the Kanban system. Decreasing the size of work orders or formatting work packages for repetitive work is an effective way to control production using the Kanban system. For the Kanban system to operate effectively, it needs to be systematically approached before the start of the make-ready process of scheduled tasks.

POSSIBLE AREAS FOR FURTHER RESEARCH

The present study was limited in the amount of time and number of cases; it may be worthwhile to focus future research on different uses for the Kanban system. The issues that need further research are categorized as follows:

- The participation of all stakeholders and the integrated use of the Kanban system to make the entire construction production system efficiently.
- Development of a general model that has the advantages of the Kanban system integrated with IT systems. Previous research approaches to the Kanban pull systems included simulation, mathematical, and stochastic modelling (Uzsoy and Martin-Vega, 1990).

REFERENCES

Arbulu, R., Ballard, G., and Harper, N. (2003). "Kanban in Construction." Proceedings of the 11th annual conference, International Group for Lean Construction, Blacksburg, VA.

Chase, R. (1973). "Production and Operations Management: A Life Cycle Approach." *Richard D. Irwin*, Homewwod, IL.

Hall, R. (1983), "Zero Inventory." *McGraw-Hill*, New York, NY.

Huang, P., Rees, L., and Taylor III, B. (1983). "A Simulation Analysis of the Japanese JIT Techniques (with Kanban) for Multi-Line, Multi-Stage Production Systems."

Decision Sciences, Cambridge University Press Vol. 14. Cambridge, United Kingdom.

Ohno, T. (1988). “Toyota Production System: Beyond Large scale Production.” *Productivity Press*, Cambridge, MA.

Shingo, S. (1988). “Non-stock-production: The Shingo System for Continuous Improvement.” *Productivity Press*, Cambridge, MA.

Singh, N. and Falkenburg, D. (1994), “Kanban Systems-In Handbook of Design, Manufacturing, and Automation.” *John Wiley*, New York, NY.

Uzsoy, R. and Martin-Vega, L. (1990), “Modelling Kanban-Based Demand-Pull Systems: A Survey and Critique.” *Manufacturing Review*, Vol. 3, 155~160.