ABSENCE IN THE PROVENANCE? LEAN CONSTRUCTION AND ITS APPLICABILITY IN JAPAN

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ABSTRACT

The Toyota Production System (TPS) is generally accepted as the origin of the lean principles, and thus Japan can naturally be perceived as its provenance. However, ironically, dialogue on Lean Construction (LC) has been limited in Japan, and almost gives a perception that LC is not applied in Japanese construction projects. The authors explored the reasons for the apparent absence of LC in Japan, and found two potential causes: (1) TPS has been constantly evolving and (2) some of the concepts of LC have already been woven into the Japanese construction industry without awareness that these concepts in fact constitute LC. In other words, it may be said that misperception and unawareness may be the potential causes of the apparent absence of LC in Japan.

The paper further explores the applicability of LC to Japanese construction projects by investigating and organizing the following: (1) examples of application of the LC method at conventional Japanese construction sites, (2) LC methods that have not yet been applied to construction projects but can be considered to be applicable, and (3) lean construction methods that are likely to be inapplicable to construction projects. Through this process of investigation and organization, the authors have made a LC project plan proposal.

KEYWORDS

Lean construction, Improvement/kaizen, Theory, Definition, Standardization

INTRODUCTION

LEAN CONSTRUCTION AND THE ABSENCE OF DIALOGUE IN JAPAN

The genesis story of lean construction is one that is fairly well known and commonly agreed upon: The Toyota Production System (TPS), devised by Toyota Motors, was generalized into a set of five principles that would later become known as “Lean Thinking” (Womack and Jones 1996):

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1. Precisely specify value by specific product
2. Identify value stream of each product
3. Make value flow without interruptions
4. Let the customer pull value from the producer
5. Pursue perfection

However, as Bertelsen points out, "the five principles are not the whole lesson learned when studying Japanese sources such as Shigeo Shingo and Taiichi Ohno". Both of these fathers of Lean Production principles deserve credit, but the latter seems to be preferred due to his work being "very specific" but "not provide management principles in the form Western managers seem to prefer them".

From a practical perspective, the two core concepts of TPS are the "Just-in-time" method which allows for efficient operation of the production line, and the *jidoka* method that automatically stops the production line or visualizes the problem when a malfunction occurs. When Lean Thinking is applied specifically to construction, the concepts recrystallize as Lean Construction.

Interestingly, in Japan, there is a shortage of discussion regarding Lean Construction. Therefore, there seems to be no comprehensive work that has looked into the dialogue that has taken place in Japan e. For example, a search query on the website of the Japan Society of Civil Engineers with the keyword "lean construction" is only able to discover one full paper on the topic (Nakagawa 2005). Searches on other journal archives also yield similar results.

One possible explanation for this is that some of the Lean Principles had already been embedded into the fabric of Japanese production and business processes, outside of Toyota. For example, Taiichi Ohno wrote a non-scholarly but popular and practical book on TPS in 1978. Although much of the dialogue about Ohno are about manufacturing and production, it would not be surprising if the works of this prominent figure may have affected other industries including construction without awareness.

EVOLUTION OF TPS

A direct analogy of these two concepts to LC would be "improvement in productivity of construction" in place of "Just-in-time" and "quality assurance" in place of "*jidoka* to eliminate defective parts". Due to the importance of these two concepts in TPS, the authors suggest that it would be important to revisit how these two concepts have evolved in recent years, and to map them out using Civil Engineering terminology.

The "Just-in-time" method was first introduced to a Toyota factory in 1938. Evolution of this method has continued ever since, but most of this evolution happened within the realm of productivity improvement. In recent times, "Just-in-time" has branched out into levelling standardization and production management, and have evolved dependently.

Figure 1 is a bird's eye-view of the results of this evolution using civil engineering terminology. As the figure shows, TPS tools today are generally seen as a method of quality assurance, process management and cost management. A concept that is clearly defined in TPS but does not exist in conventional execution management is the combination of TPS tools and "continuous improvement"

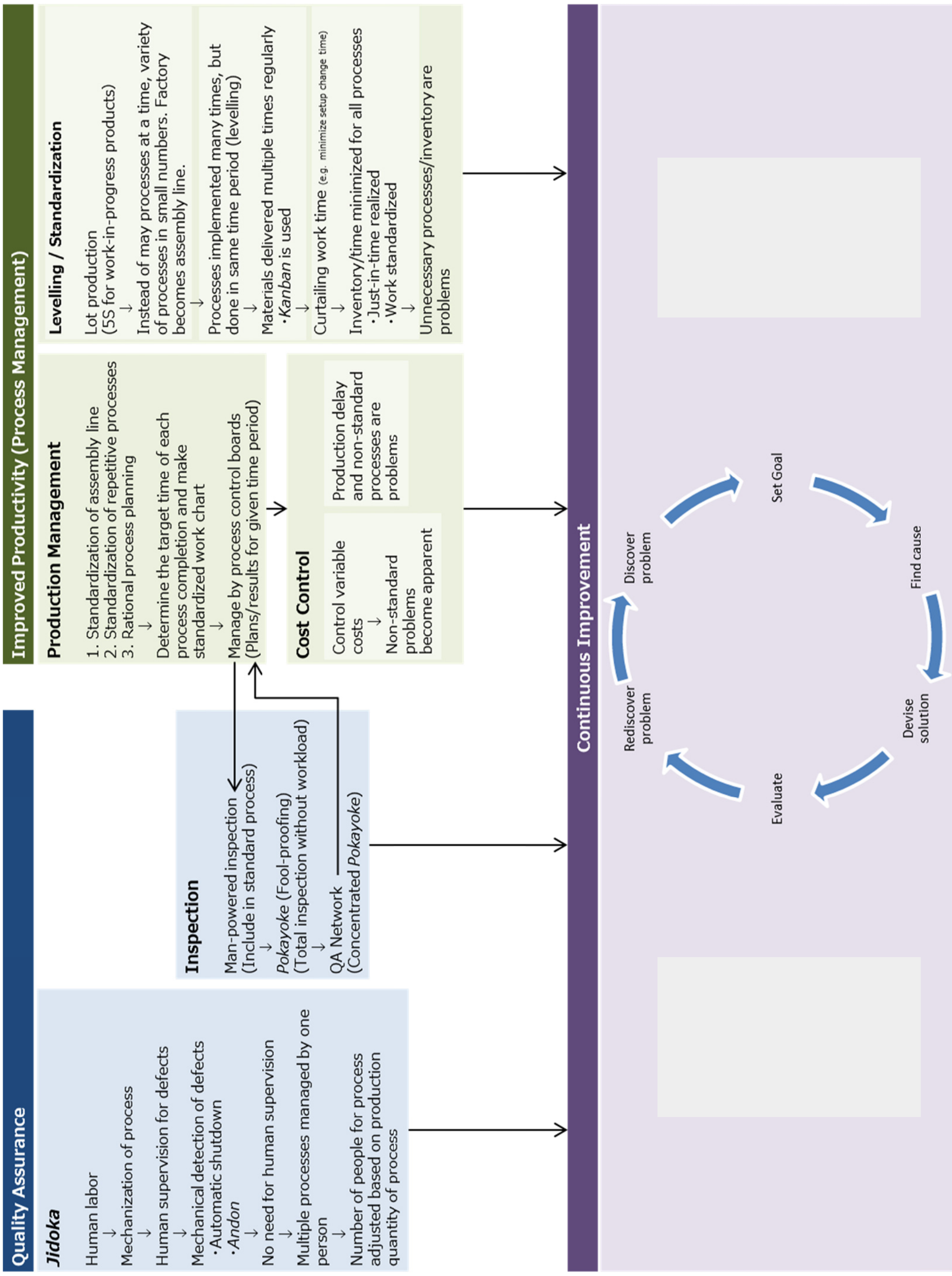

Figure 1: Evolution of TPS (with Civil Engineering Terminology)

In order to distinguish the various ways of determining “target time” of production management (“improved productivity” in Figure 1), this paper categorizes the determination of “target time” in the following three ways: (A) standardization of the assembly-line, (B) standardization of repetitive processes and (C) rational process planning. It can be understood that A corresponds to TPS at Toyota factories, C corresponds to the Last Planner System, and B corresponds to construction projects that are similar to A in construction sites. Chapters 3, 4 of this paper take B into consideration.

With the current status of TPS and all three methods of target time determination (i.e. the abovementioned A to C) in mind, one natural question might be “what might LC look like of the latest evolution of TPS was taken into account?” The authors propose below a mildly modified definition of LC may be proposed as a thought experiment to instigate discussion about the current state of LC and its applicability in Japan.

“Lean Construction is a management technique in construction sites that include the characteristics listed below.

(1) Quality assurance through automatic discovery of defects and malfunctions through mechanical determination.

(2) Actualizing waste-free and high productivity by determining the “target time” through standardization of processes and/or rational process planning and clarifying the difference between the target time and the actual results.

(3) Discovering the problems and continuous improvement relating to (1) and/or (2).

APPLICABILITY OF LC IN JAPAN

Several of the LC techniques are already implemented in Japan. On the other hand, there are also techniques that can be expected to be applicable and effective but have not yet been applied, and techniques that are difficult to apply. Organizing and clarifying such techniques will lead to increased understanding of LC in Japan, and may in turn lead to increased adoption of LC.

EXAMPLES OF LEAN METHODS APPLIED TO CONVENTIONAL CONSTRUCTION SITES

As abovementioned, there are many examples of Japanese construction sites that have applied LC methods without the awareness that they are indeed components of LC. Below are some common examples.

(1) An equivalent of “Just-in-time” is implemented through the delivery management process. Unnecessary materials at the construction site can be obstacles but if necessary materials are lacking, the entire construction process may come to a halt. Therefore, delivery management is implemented in a way that necessary materials arrive at the site in a timely manner. For materials that have an expiry (e.g. liquid concrete, bituminous mixture), strict “Just-in-time” is implemented through a bring-on time management system.

(2) *Jidoka* has been widely used through systems like the *Andon*, where an alarm would automatically sound without human supervision when there is an unusual movement of soil or the water volume has increased. Horiguchi and

Kamura (2010) developed a *Jidoka* method that would serve as a safety measure for bridge girder launching erection when constructing a bridge adjacent to a road that is already in use. In this method, a laser barrier sensor is installed between the launching girder and the existing road. If the reflector ball that is installed on the launching girder comes too close to the sensor, an alarm would go off and the construction system would come to a halt (see Figure 2).

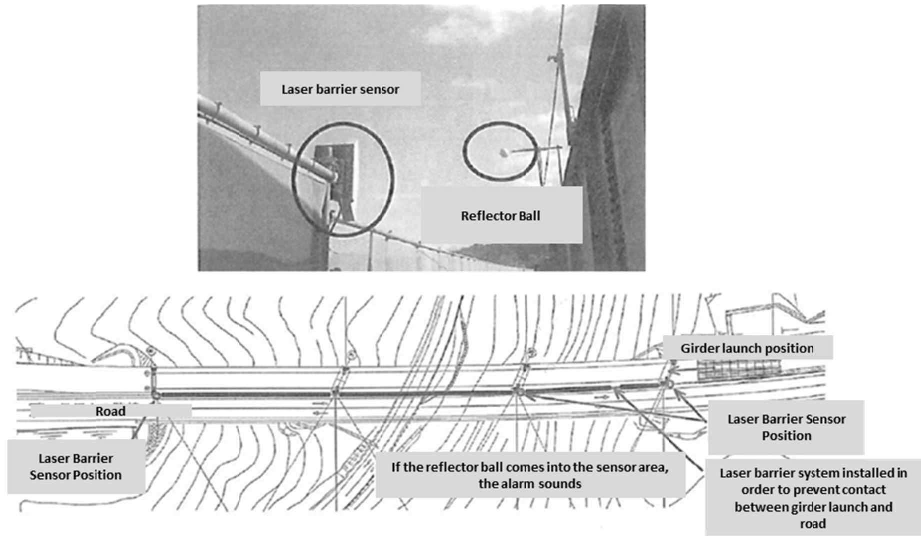

Figure 2: *Jidoka* Using a Laser Barrier Sensor

(3) A *Kanban*-like method is implemented through daily construction process meetings, where the previous processes are prepared and adjusted based on the status of the next process. The site conditions often change, so the previous processes are constantly checked by the next process team.

(4) *Pokayoke* (fool-proofing) is implemented for checking the accuracy of dimension not through the use of a scale, but through the use of a stick of a certain length called *baka-bou* (literally, “stupid stick”).

(5) The “process control board” analyzes the variance by comparing the planned and actual times, accuracy and quantity of materials.

(6) “Mechanization” is often implemented in order to cope with the lack of engineers and technical experts. Although it may be distinct from LC, which does not require major additional requirements or costs for automation, an example of mechanization may well be introduced as Japanese information-oriented-construction method. With information-oriented construction, tasks that had conventionally been carried out by humans may be replaced by computer-controlled machines. The accuracy and quality of the finished work may be measured and analyzed with the use of a Global Positioning System (GPS).

Some examples of comparisons of manufacturing and information-oriented construction methods are shown in figure 3 below.

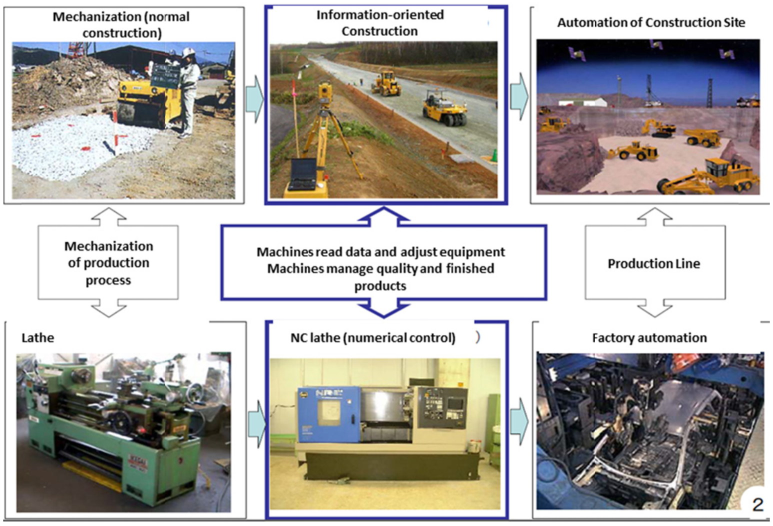

Figure 3: Examples of Mechanization through Information-oriented Construction

(7) To apply the process control board to construction, it is important to standardize the construction processes. Therefore, it can be anticipated that this method would be applied to the repetitive processes in construction. Examples of construction projects that successfully curtailed construction periods by standardizing cycle processes are explained below. Hiranohara (2011) proposed a way to curtail construction time when building track concrete slabs for bullet trains. This type of construction involves the building of and transporting of track concrete slabs to the track base. A daily production process involves building at the "slab production line", finishing at the "product finishing line" and shipping (Figure 4).

〔Production Process〕

Slab Production Line (Right four lines in the factory plan)	Product Finishing Line (Left two lines in the factory plan)
1. Product Deframe	1. Product straining
2. Mold cleaning	2. Product finishing
3. Place assembled reinforcement	3. Product Reversing
4. Attachment setting	4. Product number printing and rail enter line punching
5. Pre-placing inspection	5. Transportation
6. Placing of concrete	
7. Steam Curing	

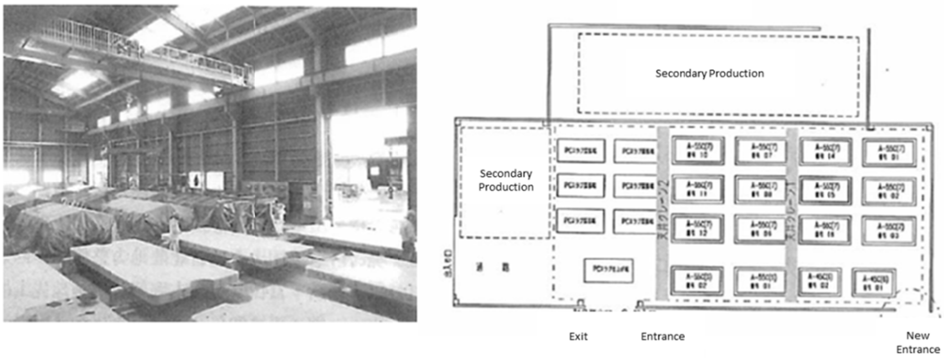

Figure 4: Production Process and Factory for Track Concrete Slabs

Calculating backwards from the entire construction period, 25 track concrete slabs need to be produced on a daily basis. However, when the standard process is designed, steps 2-5 of the "product finishing line" cannot be started until steps 1-6 of the "slab production line" are completed. Under such conditions, only one overhead travelling crane can be operated, and the operation time reaches 12 hours per day. In order to curtail this time, an additional entrance was added to the bottom right corner of the site whereas there was only one entrance at the left at first, allowing for parallel operation of the two lines. Through these measures, a standard process that can be completed in 8 hours was designed.

METHODS THAT ARE APPLICABLE TO CONSTRUCTION BUT ARE NOT YET APPLIED

Similarly to the so-called "production analysis board" of TPS, time, construction accuracy and the loss rate of materials can be managed in a construction project by comparing plans or past projects' records with the progress data of the current project. It is appropriate to refer to production analysis boards as "process control board" in construction.

In general, conventional construction projects have not been managed using detailed time-based process management as in the case of Toyota. Therefore, if the process control board can be applied appropriately, the potential for improvement in productivity may be great. In order to devise such process design, the processes must be standardized and the construction time must be measured. The types of construction projects that would be best fit for this purpose would be road pavement, retaining walls, tunnels and dams, which involve repetitive cycle processes and can be readily standardized. By standardizing the cycle processes, time, materials and human resources can be allocated, and optimization can be sought in the process of standardization. And then the production analysis board made from such process design can be utilized to compare the past-project results with the current-project results in order to discover problems and to improve. Further, in order to implement continuous improvement, methods such as the "5 whys (asking why five times)" or the "A3 method (drawing out the problem solving process on an A3 piece of paper)" may be used.

Although it is not an example of TPS in the strict sense, the example below is a construction project in which the construction accuracy and the loss rate of materials is managed effectively. Yamagami and Takahasi (2011) implemented detailed material management in a construction project to lay gravel on a cultivation road. The project was large-scaled with a construction area of 670 hectares and a site length of 80.9km, but the gravel layer thickness was only 5cm or 10cm, and thus the accurate thickness management and material loss control were challenging. In addition to the finished work management through direct daily measurements, a comparison chart was created for the design quantity and the delivered quantity and measures were taken to supervise daily gravel loss. As a result, the actual gravel loss was 20.8%, which is more than satisfactory given that the designed gravel loss rate was 20%. Further, by managing the loss rate of materials, the materials budget is also managed (Figure 5).

Name of Processor	Construction Area	Observation Station	Design		Completed			Quantity of Gravel	Average Thickness	Notes
			Width	Thickness	Width	Thickness	Length			
A Group	Site 2	0	4	0.05	4.00		495.1	120	0.08	
		50			4.05		496.1			
		100			4.04					
		150			4.03					
		200			4.05					
		250			4.04					
		300			4.00					
		350			4.00					
		400			4.00					
		450			4.01					
		456.1			4.00					
	Total				4.02		496.1			
A Group	Site 2	0	4	0.05	4.00		282.7	134	0.118	
		50			4.00		282.7			
		100			4.00					
		150			4.01					
		200			4.00					
		250			4.00					
		282.7			4.00					
	Total				4.00		282.7	134	0.118	

Figure 5: Process Management Table for the Accuracy and Loss Rate of the Gravel Fill

METHODS THAT ARE DIFFICULT TO APPLY TO CONSTRUCTION

The method in Figure 1 to “implement a variety of processes in small numbers, but many times, instead of implementing processes in large numbers at a time” seems to be difficult to apply to construction at this time because generally, construction sites increase efficiency by cutting down on the number of set-up changes. Furthermore, since construction is a project-by-project production, it is difficult to level production volumes by calculating the necessary quantity from a monthly order forecast from the vendors’ side.

THEORETICAL PLANS FOR APPLICATION OF LC

STANDARDIZED WORK CHART

In TPS, standardized processes are defined not only in terms of the procedure but also in terms of the exact number of seconds that the process is expected to take. This is possible only because the production quantity is fixed. However, in the case of construction, the site is in the outdoor wild full of contingencies, not in a controlled indoor factory environment. Hence, processes were prescribed on a daily basis, and prescriptions at a highly granularity had not been pursued.

This paper considers a case in which LC is implemented in a supposed paving project for a highway, which would be an example of a repetitive cycle process. The standardized work chart for the stabilization of the subgrade in supposed paving is shown in Table 1. A case in which no unexpected troubles or contingencies occur is imagined to set the time standards for the process control board. Contingencies will be taken into account when the process control board is applied in reality.

Table 1: Standardized Work Chart for a Supposed Paving Project

	Step	Action	Safety Tips	Standard Time
1	Unevenness Correction	Transport gravel with a dump truck	Set safety staff and guide correctly	2 hours 30 min
2	Spraying Stabilizer	Mark on the road for each ton of stabilizer	Always use mask when spraying	3 hours 32 min
3	Process after spraying	After spraying stabilizer, mix evenly with skeleton bucket. At that time, check that the depth is 70cm.	Keep aware of underground pipes when mixing	2 hours 13 min
	⋮	⋮	⋮	⋮
10	Marking	Measure dimensions of structures involved, and design on the surface. Temperature for staying should be 180 - 240 degrees	Always work with specialist	3 hours 43 min

Table 1 is a work instruction for a cycle process in a paving construction project. One cycle process can be completed by implementing ten different detailed steps in a given order. This becomes the basic unit, and the entire process can be completed by repeating this cycle process. In order to devise a process design, the required time for each of the ten detailed steps need to be measured. When measuring, the time elapsed by the most experienced worker should be used. If the total time necessary for the ten steps is 30 hours and 12 minutes, this becomes the standard time for this process. When determining the construction progress, this standard time will be used as a benchmark.

PROCESS CONTROL BOARD

The technician in charge at the prime contractor can implement daily control using the process control board if the basic unit and standard time of one cycle process is already determined. In the example above, if process (1) of Table 1 is started from the beginning, the process should be completed by 10:30, so a line will be drawn at 10:30 of the plan column of the process control board (Table 2). In the same manner, process (2) is expected to be completed at 15:02, so a line should be drawn at that position.

There is no break time at which records can be taken until noon, so all of the morning processes and results are to be recorded at noon. In this example, process (1) was delayed by 30 minutes, so a line would be drawn at 11:00 at the result column in Table 2. Further, the actual cause of the delay, which is "machine malfunctioning", is written in the "cause of delay" column. In the afternoon, the same recording process is to be carried out when the processes are completed at 17:00.

In TPS, an "problem" is defined as the "status in which there is a difference between the target time and the actual time". According to this definition, if the plan is delayed, these must all be perceived as "problems" in the management of the process control board. Technical supervisors can grasp an idea of the progress of a site by looking at the process control board. If they feel that there is a major problem, he/she must give accurate and appropriate orders to improve the situation.

Table 2: Process Control Board

Time	Plan	Result	Cause of Delay
8:00～9:00	(1)process 2hr30min		
9:00～10:00		(2)	Machine problem
10:00～11:00			
11:00～12:00	(2) process 3hr32min		
13:00～14:00			Human error
14:00～15:00		(2)	Machine problem
15:00～16:00	(3) process 1hr58min (34min remaining)		
16:00～17:00		(3)	

PROBLEM SOLVING METHOD

When there is a difference between the target time and the actual time, the site worker must meticulously analyze the cause by continuing to ask "why", and should never give up until the true cause is identified. The premise here is the ideal that "problems should never be repeated". Further, by devising measures to cope with the problem and implementing them, the measures will be evaluated. This process is repeated until the expected results are fully accomplished. If each and every one of the site workers strictly followed this principle, problems would no longer arise. If anyone is lacking this principle, the project is prone to various problems.

For items that require the reporting or permission of one's supervisor, the particulars should be summarized in an A3 sheet of paper for reporting and approval, as shown in Figure 6. Further, the A3 method could also be used as a part of the performance rating system of technicians. In this case, themes for improvement would be registered at the beginning of the business year, and the results would be presented at the end of the business year. Through such measures, communication about the details of the problems will become efficient and smooth.

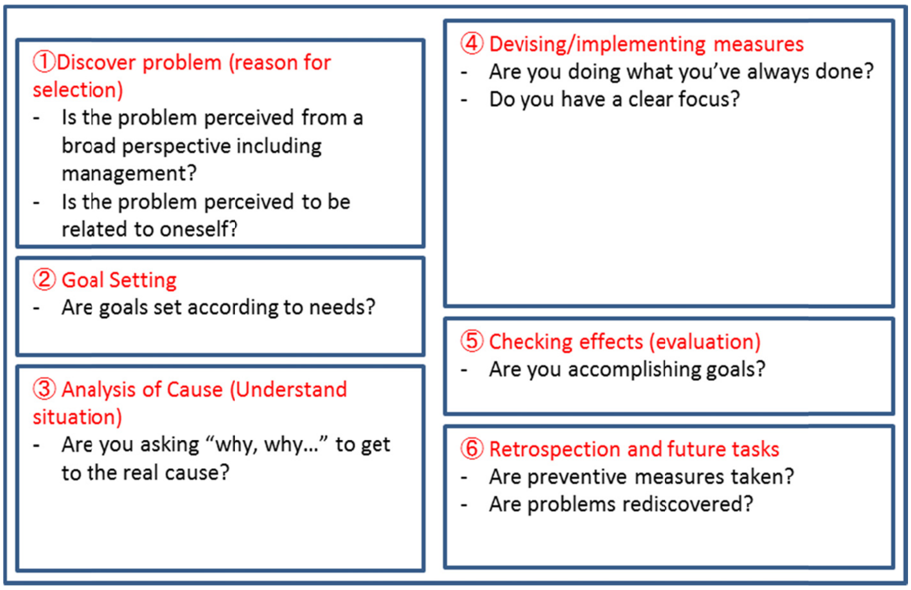

Figure 6: Reporting Format of the Problem Solving Process using an A3 Sheet of Paper

SUMMARY

The Toyota Production System was systemized by practitioners like Ohno, but the underlying philosophy has been interwoven into Japanese society and businesses. Therefore, bits and pieces of the Lean Principles have been applied throughout Japan, and the construction industry has not been an exception. However, the side effect has ironically been that because Lean Principles have been existent in Japanese construction even before the term was coined, much of the Japanese Civil Engineering sector had not been eager to revisit the Toyota Production Method, and thus led to a lack of dialogue and incomplete implementation of LC.

This paper revisited the Toyota Production Method, identified the recent evolutions in the method, proposed a mildly altered definition of LC as a thought experiment to think what the definition of LC, especially embodied in the two core concepts (i.e. just-in-time and *jidoka*), that are arguably most relevant to construction projects, if the evolved Toyota Production Method had been projected onto the construction industry today.

Further, this paper investigated past construction projects in which LC methods had been used without knowing in Japan, so as to explore some of the necessary conditions for spreading LC in Japan. Finally, the paper showed a theoretical planning example in which LC methods are utilized.

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