Applying Lean Production A3 to Enhance Construction Work Flow

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Abstract: Pioneered by Toyota, the A3 Report has been shown to effectively improve manufacturing efficiency, but can this lean manufacturing innovation be adapted to the construction industry? This study applies the A3 Report to improve work flows at a real stone pavement construction site. Value stream mapping is first used to identify onsite waste. Improvement motivation, objectives, plans, and schedules are explained using the A3 Proposal Story to accelerate approval. Improvement progress is then reported using the A3 Status Story at key milestones. Improvement effects are visualized using charts and unsolved problems are listed as future tasks. Once the objective is achieved, the improvement process and results are graphically summarized using the A3 Final Report. The A3 problem-solving approach is found to effectively improve communication among construction project stakeholders. This study validates that the A3 techniques can be applied to enhance work flows in the construction industry.
[Chien-Ho Ko, Pei-Chen Tsai. **Applying Lean Production A3 to Enhance Construction Work Flow**. *Life Sci J* 2013; 10(2): 2409-2416]. (ISSN: 1097-8135). http://www.lifesciencesite.com. 333

Keywords: Lean production; A3; construction work flow; improvement; visualization

1. Introduction

The construction industry is characterized by high costs, complex work interfaces, and outdoor operations (Dykstra, 2011). Work progress and costs are influenced by worker proficiency, material sufficiency, weather, and construction methods (Aliverdi et al., 2013). Lean production, also known as the Toyota Production System (TPS), is a managerial philosophy which has recently been adopted by a wide range of enterprises in a bid to enhance competitiveness. Numerous studies have shown that lean production can reduce waste in production processes and increase customer value (Womack et al., 2007). Lean production has been successfully applied in manufacturing and has had an evolutionary impact on managerial methods worldwide.

Lean production concepts were first introduced to the construction industry in the 1990's (Koskela, 1992). These so-called lean construction practices can be seen as a means of adopting theories and methods from lean manufacturing to enhance construction management performance (LCI-Taiwan, 2013). Several studies have shown that lean construction can break through the traditional trade-off between cost, speed, and quality (Best and de Valence, 2000; Ballard, 2000; Arayici et al., 2011; Ko and Chen, 2012).

One element of the TPS is the "A3 Report" - a method of graphically visualizing problems and solutions (Flinchbaugh, 2009a). The A3 Report is frequently used as a tool for sharing important information, requesting assistance and suggestions, and achieving consensus (Flinchbaugh, 2009b). This tool has been widely adapted in a range of industries. For example, Clark (2009) applied the A3 Report to improve Electronics Manufacturing Services (EMS), claiming that it can help engage an entire company in a sustained improvement effort. Maryati Mohd et al. (2012) and Jimmerson et al. (2005) applied the A3 Report in health care to eliminate waste such as waiting (employee, patient, machine, and information), inventory (material or patients), motion (unnecessary staff movement), and overproduction (unnecessary labs/visits). Womack (2010) suggested that A3 could be used as the foundation for the development of sustainable lean enterprises and for the development of countermeasures to help organizations navigate the current recession.

Construction is not manufacturing. Although previous studies have demonstrated the effectiveness of the A3 Report in manufacturing and health care, its applicability in the construction industry has rarely been discussed. This study hypothesizes that the A3 Report can be used as a tool to improve construction work flow. To test the hypothesis, A3 is applied to a real construction site. The remainder of this paper is organized as follows. The next section provides background information on the A3 Report and waste in the production system. Section 3 explains the methodology used to test the hypothesis. Section 4 provides background for the stone pavement construction used in the case study. Section 5 reviews the impact of A3 Report application on work flow improvement in stone pavement construction. Finally, the paper concludes with suggestions for future research directions.

2. Background Information

2.1. A3 Report

Toyota's "A3 Report" takes its name from the size of the sheet of paper it uses, as A3 is the largest standard paper size that can be accommodated by a regular fax machine, which was a critical communications tool used by Toyota at the time (Liker and Meier, 2005). In the process, all information required for solving a particular problem is represented on one side of an A3 sheet, forcing stakeholders to focus on only the most critical information. The report systematically presents the problem, solution, and results in terms of stories illustrated by figures and graphics (Chakravorty, 2009). Through the "Proposal Story," "Status Report Story," and "Final Report," the A3 Report identifies waste and explains improvements (Liker, 2003). At the outset, the Proposal Story is used to achieve consensus on defining the problem and to determine whether it is actionable. In this stage, value stream mapping is frequently used to identify the problem (Rother and Shook, 1999), which is then put into the context of the overall project. The Proposal Story also addresses improvement objectives, options, and guidelines. The Status Report Story provides the latest information on improvement progress in reference to improvement milestones. This story also presents the assistance, suggestions, and resources which may be required for the improvement. In the third stage, the Final Report reviews the process deliverables, specifically waste removed and goals achieved, and highlights the success factors in the problem-solving process. Future improvement items are also documented in this stage. Figure 1 summarizes the A3 problem-solving report process.

2.2. Production Waste

Lean methods have been increasingly used to optimize workflows by eliminating waste (Schweikhart and Dembe, 2009), defined as activities that add no value to the product or service (Singh et al., 2010). Ohno (1988) proposed the following as the seven most common types of waste in production systems:

1. Overproduction: Manufacture of products in advance results in additional costs, time, and space requirements.
2. Waiting: Processes are ineffective and time is wasted when staff members await their next assignment.
3. Transportation: Moving product and material between manufacturing processes adds no value.
4. Inappropriate processing: Overly elaborate and expensive equipment can result in waste in an attempt to unnecessarily raise quality standards.
5. Inventory: Excessive raw material inventory and incomplete work pieces may incur storage and maintenance costs.
6. Unnecessary motion: Task design requires staff to move inefficiently (e.g., bending, reaching, etc.).
7. Defects: Defective products must be corrected and re-inspected, wasting time and money at each stage.

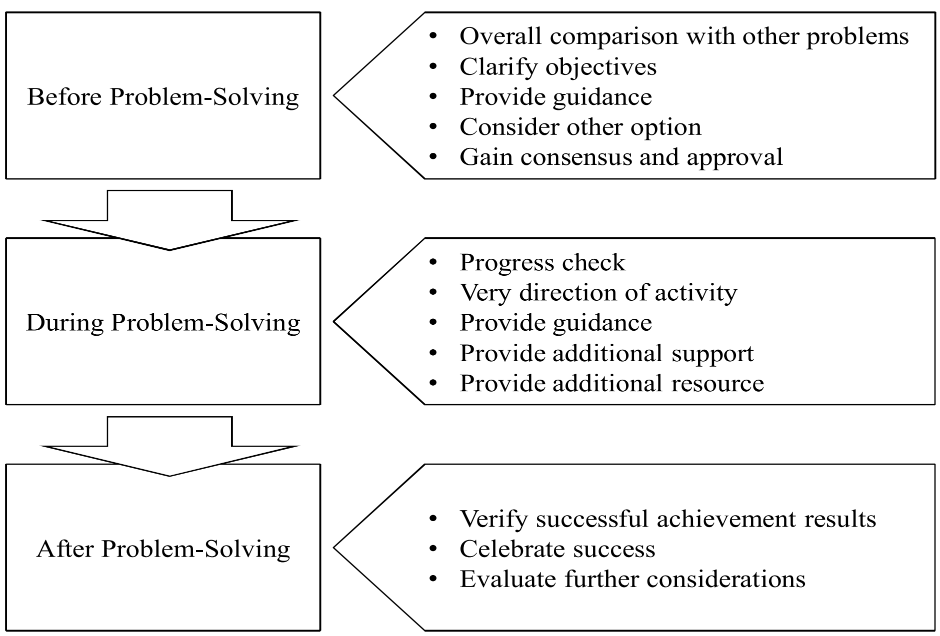


Figure 1. A3 problem-solving report process (Adopted from Liker, 2003)

3. Research Method

Figure 2 illustrates the research process. A3 Reports are used to identify construction site problems. Solutions are then developed to eliminate waste. Finally the new process is standardized and executed.

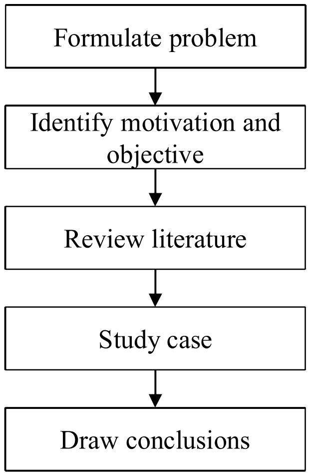


Figure 2. Research flow

1. Formulate problem: This study is interested in enhancing construction work flow, and the process begins by reviewing difficulties faced in construction management. This activity relies on two main resources: interviews with experts and previous research.
2. Identify research motivation and objectives: The objective of this study is to enhance construction work flows using lean methods, specifically the A3 Report, a simple visualization tool for improvement.
3. Review literature: An extensive survey was conducted of concepts and theories connected to the formulated problem to broaden the knowledge base. The literature on production waste was reviewed and A3 Report application procedures were studied. Application to construction work flows was also investigated in a real construction site.
4. Study case: To test the developed hypothesis, the applicability of the A3 Report was studied using a real construction site, specifically for stone pavement construction. The A3 Report was applied to analyze the workflow and represent the problem-solving method.
5. Draw conclusions: Improvement results are represented using the A3 Report. Implications of the results are discussed, along with suggestions for further advancement.

4. Stone Pavement Construction

Stone pavement construction covers a floor with stone tiles to improve pavement durability and/or aesthetics. Figure 3 illustrates a stone pavement construction site. The work entails the use of materials including sand, cement, water, stone tiles and additive following operation sequence shown in Figure 4. The operation is generally performed by two workers, a skilled paver and an assistant. Operational tasks shown in Figure 4 are primarily carried out by the paver, with the assistant stirring the paste, arranging the tiles, and fetching materials and tools as needed.


Figure 3. Stone pavement construction site

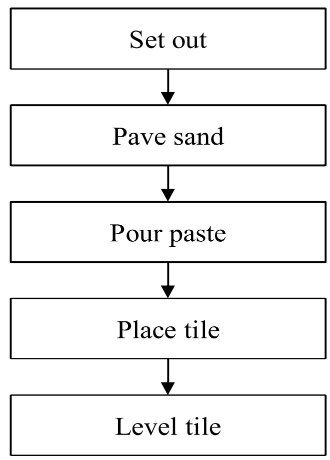


Figure 4. Stone pavement construction procedure

5. Case Study

5.1. A3 Report Application

The case study focuses on decorative stone pavement construction conducted by a subcontractor in a cultural park construction project in southern Taiwan, with a budget of about USD250, 000. The A3 Report is used to represent stories related to the stone pavement construction. The improvement proposal is given to the workers and foreman. Finally, the A3 Report is used to visualize improvement results.

A Proposal Story is first prepared to explain problems in the stone pavement construction process. Value stream mapping is another visualization tool originally developed by Toyota for analyzing and designing the flow of materials and information required to produce a product or service (Rother and Shook, 1999), and is used here to identify problems in the stone pavement construction. The value stream mapping of the case study is shown in Figure 5. In the figure, the paver and his assistant spent a considerable amount of time searching for tools and waiting for their assignments. Appropriate improvements are established, with tools located in pre-established locations to reduce time spent on searching. The assistant's role is expanded to increase collaboration, thus reducing the time the paver wastes while waiting for his assignment. An implementation plan is developed with an itemized improvement schedule. Expected results are also listed in the report, along with unresolved issues which require resources and support. The report is used to secure immediate approval of the proposal by the foreman and superintendent, allowing for the establishment of consensus and acquisition of resources. The developed Proposal Story for the case study is shown in Figure 6.

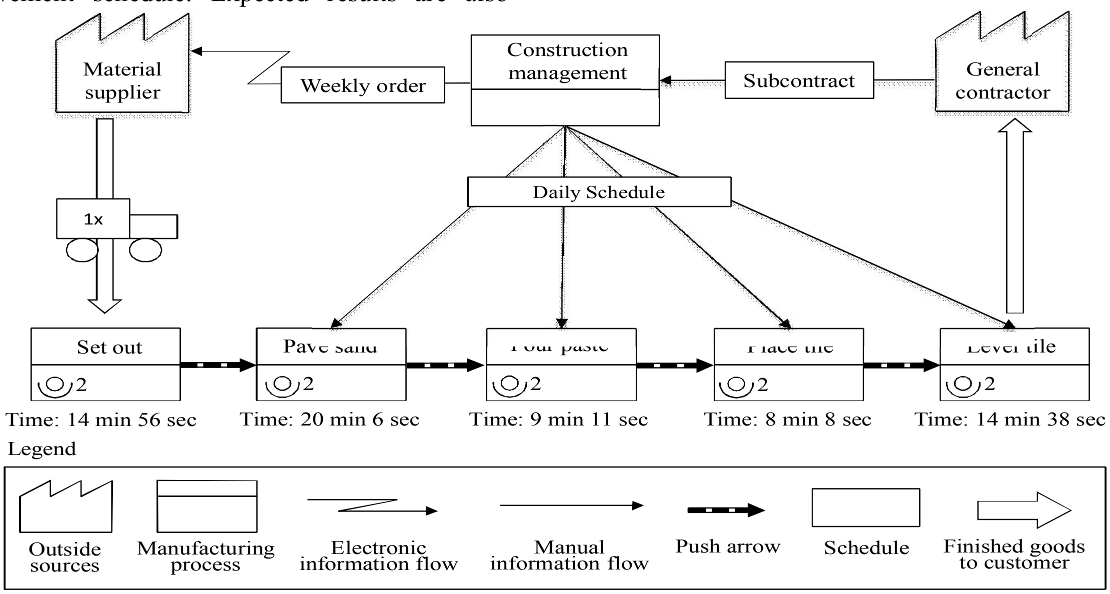


Figure 5. Current-state map

Stone Pavement Construction

I. Introduction

Stone pavement construction must be completed before project end, but if it is completed too early, it may be damaged by other construction tasks. Thus, stone pavement construction is usually rushed. Reducing lead time for this task is crucial for project success. Value stream mapping reveals waste through waiting and searching for tools, thus extending lead time.

II. Proposal

This study focuses on reducing lead time through eliminating waste. Tool locations and operational process are adjusted to reduce time previously spent on searching for tools and waiting. Tools are located in pre-assigned places, and paving assistants are given a more active role in the paving process.

III. Plan

Required condition: Reason for the required condition	Expected effect	Responsibility
Pre-assigned tool location: workers search for tools.	Reduce time for searching tools	Worker
Worker collaboration: One worker is waiting for assignments.	Reduce waiting time	Worker

IV. Unresolved issues

How can the two workers work more collaboratively? The foreman, paver, and assistant paver can provide suggestions.

V. Action plan (schedule)

August 22: Discuss and redesign the collaboration process. Conduct the new process.
August 29: Final report.

Author: Ko & Tsai Date: August 15

Figure 6. Proposal Story

The Status Report Story is updated at key milestones to demonstrate improvement progress, as shown in Figure 7. The Background table briefly explains improvement motivation whereas the Objectives table highlights improvement objectives. The Implementation table addresses how the improvement plan is carried out for the items shown in the Proposal Story's Plan table. The Total Effect table uses a graphic to provide a comparison before and after improvements. Time required for stone pavement operations were effectively reduced by establishing a regular location for tools and training the assistant paver to provide resources the paver needs for the next step. Finally, unresolved problems and future actions are listed to acquire further support and resources. In this case study, the workers involved still need to increase their familiarity with the new process.

Stone Pavement Construction

I. Background

Stone pavement construction is a necessary part of the project. Value stream mapping revealed waste resulting from waiting and searching for tools, contributing to long lead times.

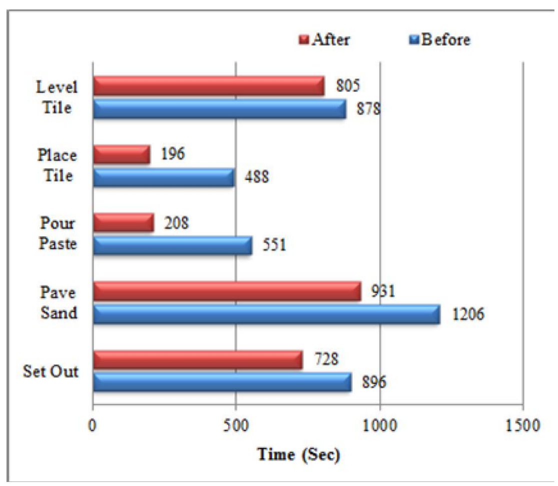
II. Objectives

Reduce lead time by establishing a regular location for tools and by enhancing worker collaboration.

III. Implementation

Pre-assigned tool location	Preparing required tools and pre-determining a regular place for tools reduces time currently spent on searching for tools and waiting.
Worker collaboration	The assistant paver actively helps the paver prepare materials and find tools as opposed to passively waiting for work assignments.

IV. Total effect



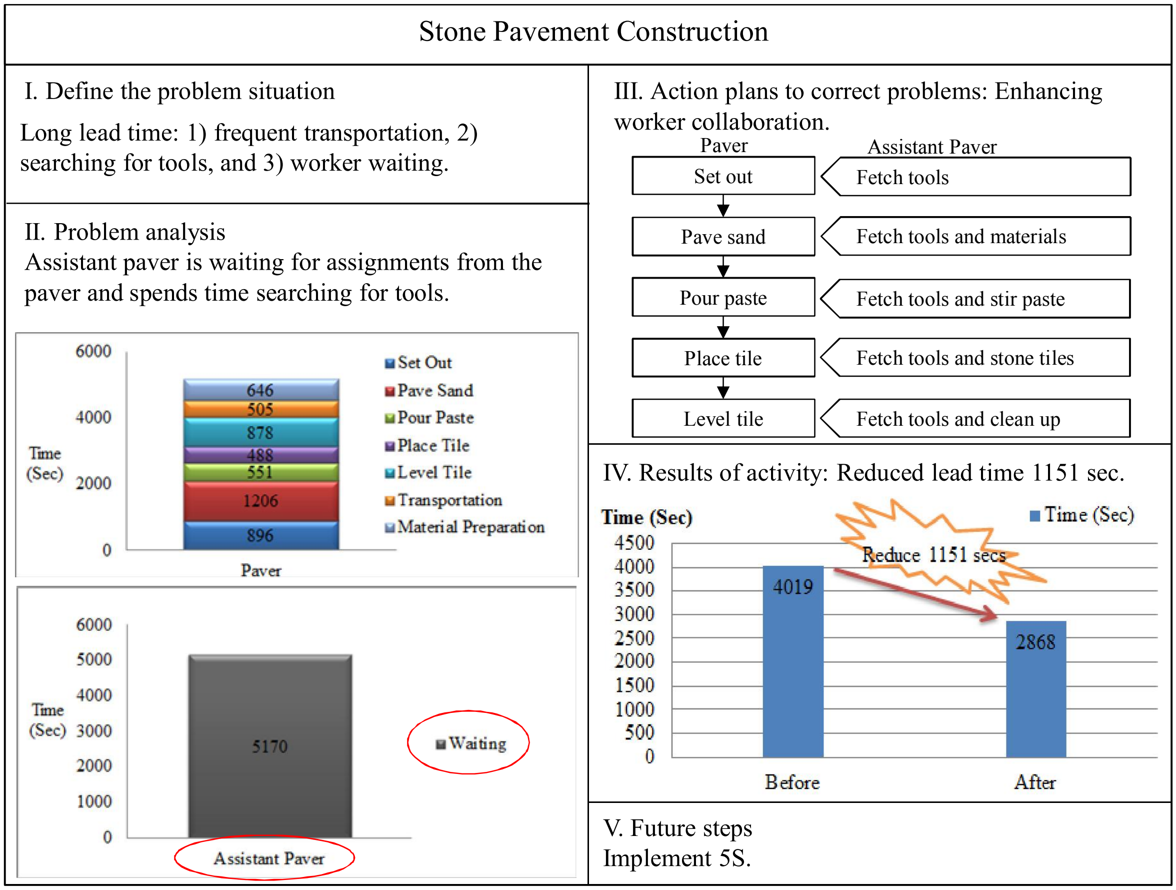
V. Unresolved problems / Future actions

The assistant worker is not currently familiar with pavement construction operations. Workers are becoming familiar with the new process.

Author: Ko & Tsai Date: August 22

Figure 7. Status Report Story

Once the desired results are achieved, the complete improvement result is represented in the Final Report, as shown in Figure 8. "Define the problem situation" explains the improvement motivation. "Problem analysis" visualizes the operational time for the paver and his assistant, highlighting the root cause of waiting waste. "Action plan" illustrates methods used to improve the stone pavement construction process, i.e. having the assistant fetch tools and materials in advance. "Results of activity" visualizes the improvement achievements. Using the proposed method, the time required to pave 30 m^2 can be reduced by 1151 seconds. The value stream mapping of the improved process is shown in Figure 9. Finally, future steps are proposed, including so-called "5s" (i.e., sort, set in order, shine, standardize, and sustain) for the stone pavement construction site.



Author: Ko & Tsai Date: August 29

Figure 8. Final Report

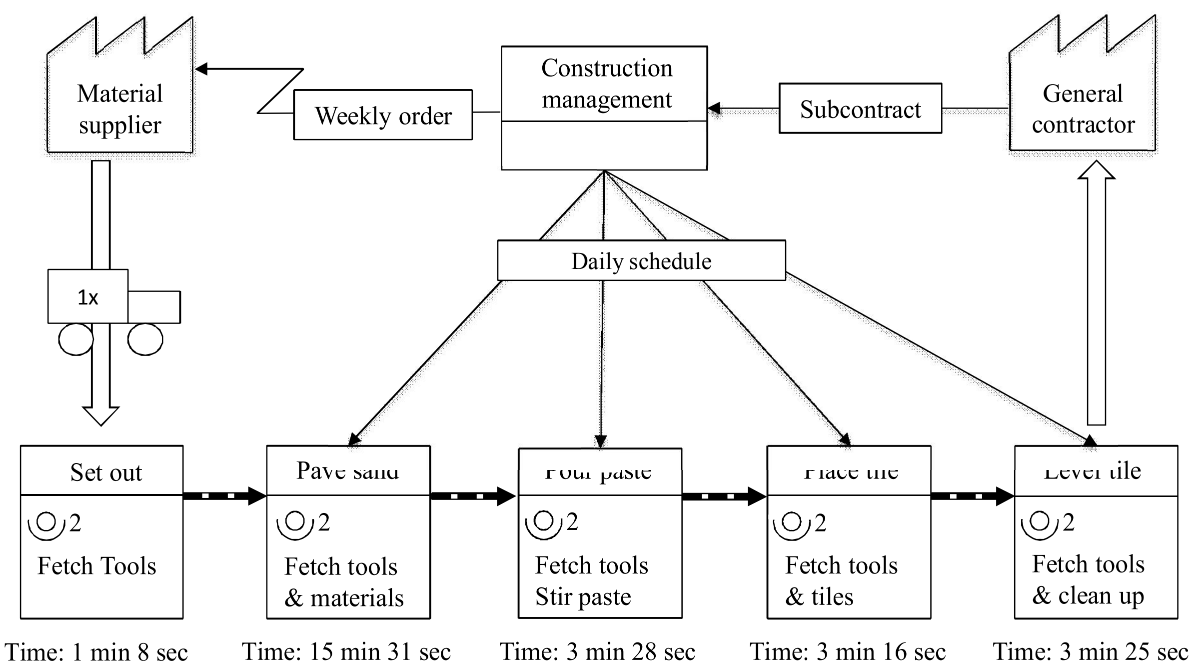


Figure 9. Value stream mapping of the improved process

5.2. Discussions

This study uses a lean method, the A3 Report, to reduce the lead time required for stone pavement construction. Value stream mapping revealed significant waste due to waiting, and the root causes of the waste were identified in the course of preparing the A3 Report. Suggested improvements include positioning tools in a pre-established location, with the assistant paver fetching tools and materials in advance. As a result, operational lead times are reduced. The A3 Proposal Story provides concise information, thus reducing approval times in meetings. The improvement plan is applied to the construction site, with the status report providing the workers, foreman, and superintendent with up-to-date information. Once the improvement objectives are achieved, the improvement results are graphically displayed in the A3 Final Report, providing participants with a visual representation of the whole improvement process and encouraging the development of best practices. Also, acknowledgments can be issued to those who assist in the improvement process.

6. Conclusions

This study suggests that the A3 Report can be used to improve construction work flows, using a real stone pavement construction project as a case study. Value stream mapping is used to identify operational problems. The Proposal Story illustrates problems, improvement plans, and schedules to reduce approval times. Improvement progress is represented using the Status Story at key milestones. Finally, the Final Report is used to summarize the improvement results. This study shows that the A3 Report can be applied to problem solving in the construction industry, thus enhancing construction work flows.

The case study shows that value stream mapping and the A3 Report can be used as tools to efficiently identify waste and integrate processes, providing concise information and visualized figures to improve communications efficiency. This research represents a pilot application of the A3 Report in the construction industry. Although the case study is restricted to a very limited domain, it provides encouragement for the application of the A3 Report to overall project improvement. Future studies could apply the A3 Report to improve structural engineering and cost analysis.

Acknowledgements:

The authors would like to thank the participants of the investigated construction site for their support and cooperation. Special thanks are due to undergraduate student Jia-Cyuan Jhang who helped in data collection.

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6/18/2013