Applying the Toyota Way for Improving Formwork Engineering

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Abstract

The construction industry is labor intensive, and formwork engineering accounted for the highest ratio of labor. According to survey and analysis reported by Ministry of the Interior , formwork accounted for approximately one third of the cost for the reinforced concrete structures. However, traditional formwork process causes delivery and material wastes. The purpose of this research is to apply the Toyota way of production concepts to improve on formwork engineering. The Toyota Way of production consists of the management philosophy of the so called 4 Ps , and they were the four tiers of improvement. Tier one, "Philosophy", and the core value of which is the long term considerations emphasized in management decisions. Tier two is "Process." Its core value is to eliminate waste. The third tier is "People and partners", and the core value of which is the respect of team work. The fourth tier is "Problem solving", and the core value is continuous improvements and learning.

The present research utilized the Toyota model to make improvements on formwork engineering. The improvements include reductions in wasted resources and increasing the operational value. In the long run the model could provide a learning and growth platform for individuals, the business unit, and extended partners. It could also provide innovative thinking for improving formwork engineering

Keywords: Formwork engineering, Toyota model, value stream mapping.

Introduction

The evolution of the construction industry began from task specialization to dramatic reductions in human labor. This resulted in gradual increases in the percentage of responsibilities for specialized technicians and management personnel over the years. According to statistic results from Construction and Planning Agency of the Ministry of the Interior on average a person working in the construction industry received higher pay than other industries, and is the highest of all categories (CPAMI, 2008). In 1947 and 2004 there were ten great infrastructure projects and the new ten great infrastructure projects implemented by the government, and due to these projects the construction industry experienced double digit percentage growths within those years (Tao Han, 2000). However, after these two years of boom a flat period followed, and after which the industry entered depression (DGBAS, 2009). This contrasted sharply with the automobiles industry that possessed great potential in terms of technology, quality, and profitability. Taking Toyota Motor Corporation for example, the company (formerly Toyota textiles) began

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implementing the Toyota Production System (TPS) and Total Quality Control (TQC) in 1950 and established for itself steady growth and profitability (Li and Yang, 2009); in 2008 Toyota produced 8.79 million vehicles and took over number one spot as the largest automobiles maker from General Motors (Dong, 2009).

The construction industry is a labor intensive industry, and formwork occupies the highest ratio of labor. According to survey and analysis research reported by Ministry of the Interior's Architecture and Building Research Institute on Taiwan's construction engineering the most common type of housing construction in Taiwan is reinforced concrete that accounted for approximately 87% of the total housing construction floor area (Peng, 1991, 1992). In addition, formwork of the reinforced concrete accounted for one of the four largest cost factors. Formwork accounted for approximately 15% of the total cost for an average building, and it accounted for approximately one third of the cost of reinforced concrete structures. Therefore formwork engineering research is of vital importance for construction engineering.

The purpose of this research was to utilize the production concepts of the Toyota Way. The Toyota Way comprised of the 4 Ps as its management philosophical framework (Jeffrey, 2003), and improvements were carried out in 4 tiers: the first tier was "Philosophy", and its core value was the long term philosophy in management decisions. The present research first defined the core value of formwork engineering, and then improved formwork engineering through long term sustained management concepts. The second tier was "Process", and its core value was to eliminate waste. The present research utilized this concept to draft a value stream mapping for formwork engineering in order to eliminate wasteful concepts to inspect the value of every step of work implementation. The third tier was "People and Business Partners," and its core value was to respect team work, and nurture superior engineers and then form a superior implementation team. The present research utilized this concept in terms of learning with the formwork suppliers in standardizing work implementation process, and then ultimately developed into extended business partners. The fourth tier was "Problem Solving," and its core value was continual improvements and learning. The present research established problem solving and sustained improvement frameworks in order for formwork engineering to effectively adjust and accommodate resources, ensure common understanding among personnel, and continue to solve root problems to promote organizational learning.

Literature review

Toyota model of production

Lean production was the core of the Toyota way of production. Toyota was formerly a textile company founded by Mr. Toyota Sakichi. Upon Mr. Toyota Sakichi's visit in the American industries he recognized the automobiles industry was the future market trend. Thus he began recruiting talents and established the Toyota Motor Corporation. Toyota investigated the car production manufacturing process and examined various resource wasting causes. The purpose of lean production was to fully eliminate waste, and provide the accurate number of materials for every process in right timing, and thus increase productivity and product quality. Waste indicated activities that did not match the standard performance of the production system, and all things that did not contribute to creating product value were viewed as waste. The founder of the Toyota Way of production, Taiichi Ohno, pointed out seven forms of production waste (Taiichi, 2004): Waste of over production, Waste of transportation, Waste of waiting, Waste of inventory, Waste of producing faulty products, Waste of actions, Waste of production processing.

The presidents of Toyota Motor Corporation, Fujio Cho, and Jeffery Liker, brought

forward the phrase, “The Toyota Way”, in 2001 and 2003 respectively. In Jeffery Liker’s book, “The Toyota Way: 14 Management Principles from the World’s Greatest Manufacturer”, 14 management principles were detailed and the 4P model of the Toyota Way was brought forward as indicated in Figure 1 (Jeffrey, 2003).

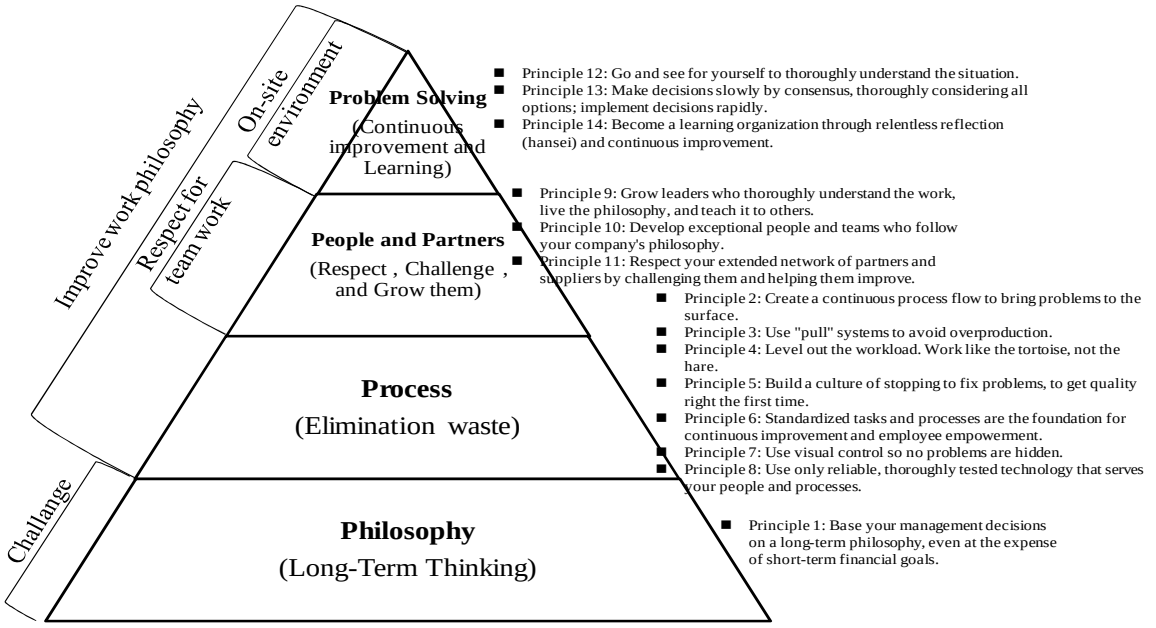

Figure 1. 4P and 14 Management Principles

The Toyota Way (4P framework)

- Philosophy:
  At the most basic level, the leader of Toyota viewed the company as a value creating tool for customers, society, communities, and people. In the beginning, the founder of Toyota, Sakichi Toyota wanted to invent a better performing weaving machine to help the women in remote villages similar to where he grew up to lead a better life. After that, Sakichi Toyota asked his son, Kiichiro Toyoda, to establish a motor company to contribute to the world. Today, all leaders of Toyota firmly remember this philosophy, and it is the basis for all other principles.
- Process:
  Toyota believed that by establishing correct processes then more correct processes would be generated. Firstly a present value stream mapping was sketched that confirmed the value of each stream. The valuable processes were smoothly and effectively conducted, and processes without value were eliminated to reduce obstacles and waste.
- People and Partners:
  Challenge your workers and business partners to pursue growth and create value for your organization. In the Toyota production regulations many tools aimed to make problems surface, and create a challenging environment that derived the thinking and growth of employees.
- Problem Solving:
  This was the continual root problem solving that promoted organizational learning. Without investigating into the root of problems then similar problems would occur again. To find actual problem solving solutions, ensuring common understanding of problems among the personnel, emphasize the necessity and benefits of problem solving, and highly effective results predictions can promote

common learning for the team and company.

14 management principles

- Principle 1: Base your management decisions on a long-term philosophy, even at the expense of short-term financial goals.
- Principle 2: Create a continuous process flow to bring problems to the surface.
- Principle 3: Use "pull" systems to avoid overproduction.
- Principle 4: Level out the workload. Work like the tortoise, not the hare.
- Principle 5: Build a culture of stopping to fix problems, to get quality right the first time.
- Principle 6: Standardized tasks and processes are the foundation for continuous improvement and employee empowerment.
- Principle 7: Use visual control so no problems are hidden.
- Principle 8: Use only reliable, thoroughly tested technology that serves your people and processes.
- Principle 9: Grow leaders who thoroughly understand the work, live the philosophy, and teach it to others.
- Principle 10: Develop exceptional people and teams who follow your company's philosophy.
- Principle 11: Respect your extended network of partners and suppliers by challenging them and helping them improve.
- Principle 12: Go and see for yourself to thoroughly understand the situation.
- Principle 13: Make decisions slowly by consensus, thoroughly considering all options; implement decisions rapidly.
- Principle 14: Become a learning organization through relentless reflection (hansei) and continuous improvement.

Formwork engineering outline

Currently 87% of national construction companies' construction projects are in the form of labor and material bidding, and only 5% of work are self-implemented (Song, 2008). The bidder would win the bid at a low price and then after cost re-evaluation subcontracts to an even lower priced work crew in order to maintain or increase profits. However, in the interest of fair wages the work crew would greatly discount specifications and schedule advancement. In addition, in order to keep operational costs down the construction companies are unwilling to make extra expenditure costs to raising construction techniques or management skills. Such a vicious cycle resulted in an anti-selection phenomenon where the worse drove out the better.

The biggest advantage of subcontract management included cost reductions, work performance increase, lower labor costs, and labor flexibility. However, its disadvantages included key technology loss, creativity development suppression, difficult quality control, schedules limited by subcontractors, difficult cost control, poor safety awareness, management difficulties, poor work qualities, no regulation abidance, and high fluidity in subcontracting personnel.

In terms of subcontractor work models there exists the phenomenon of repeated subcontracting (approximately 30%) due to prevalent multiple project subcontracting by many subcontractors. The technical works accounted for 75%, and the subcontract duration varied. This resulted in high levels of uncertainty in these types of subcontracting works. In addition, subcontractors demanded high mobility of personnel and encouraged large numbers of temporary staffing. The percentage of various contractors hiring temporary staff was on average 1.2 times more than long term staff. In addition, 80% of contractors

would use temporary staff due to the main reason of work content demand, and the secondary reason of financial concerns. Temporary workers possess the quality of high flexibility in terms of job content and job location. This also indicates the uncertainty faced by temporary workers is greater than long term workers. The income source and average wage are also significantly lower than long term workers. This accentuates their financial pressures are higher than long term workers, and on top of zero job security and lower job satisfaction levels, their views of the future tend to be more negative (Chang, 2007).

Current formwork implementation process

Formwork operation process

There are many types of formwork. According to their functions they could be divided into building purposed, factory purposed, and civil engineering purposed. According to their purposes formwork could be classified into "traditional wooden formwork" and "systematic formwork" (Liyan and Yang, 2004). The materials used include wooden formwork, steel formwork, aluminum formwork, plastic formwork, and FRP formwork. The main job of formworks were indicated in Figure 2 (Shen, 1992), which included formwork design planning, implementation diagram, material preparation, formwork processing, lofting, formwork assembly, inspection, monitoring and remediation during concrete pouring, formwork removal, and further support operations. Therefore its implementation complexity and required operation process are more complex than steel bar and concrete. However, it is important to develop long term work philosophy, reduce waste, increase formwork value, respect engineers and formwork suppliers, and create a common continual and sustained improvement and learning platform.

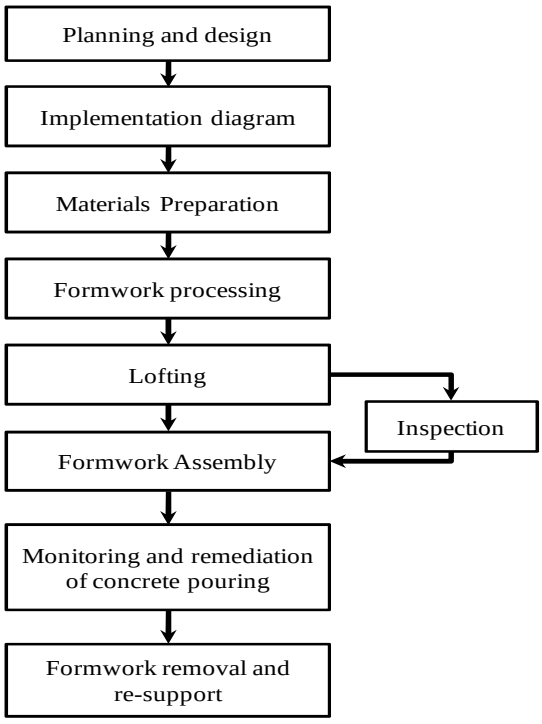

Figure 2. Traditional Formwork Operation Procedure Process

Figure 3. Actual Site of Formwork Implementation

Literature review (section Formwork engineering outline) described construction companies subcontracting to professional formwork engineering companies with overall formwork monitored by the construction companies. Planning and formwork

implementation schedule are planned by the formwork leader. The requirement of formwork operation personnel numbers are planned in advance according to schedule, structural height, shape, level of implementation difficulty, and material.

One of the authors was an engineer in a team in charge of factory construction and participated in professional formwork contractor work implementation process. At present during formwork implementation it is common that formworks are placed randomly without proper arrangement (as indicated in Figure 3). The formworks for processing are also improperly categorized. Formwork workers would cut 60x180 cm wooden formwork boards with round sawing machines into 45x60 wooden formwork boards, and resulting in unusable remaining formworks. This is an example of action and processing procedural waste. By learning the Toyota way of long term management and waste elimination concepts will generate new opportunities for the construction industry.

Formwork value stream mapping

Production and operational activities are the transformation of limited resources invested by enterprises into solid products or formless services with commercial values (Lai, 1991). The value stream mapping of traditional formwork operation procedure process was mapped according to the "Process" tier of the Toyota Way. After construction companies obtained an order from clients they would establish project engineering departments to control the overall work implementation schedule. Firstly the wooden formwork supply chain model was mapped, as indicated by Figure 4. Of which there are two types of procedure of logistics and information flow. In terms of logistics, the project engineering departments would place orders to formwork contractors, and then formwork contractors would place orders to formwork suppliers. Finally the products are shipped to the customer designated construction site. In terms of information flow, the overall formwork project schedule is jointly planned by the project engineering departments, formwork contractor owners, and formwork supplier leaders. The overall schedule advancement and completion time are then planned by the formwork leader execution department. The formwork contractor owner and formwork leader would jointly arrange the work advancement and completion times. The formwork leader would carry out related schedule plans such as formwork processing, formwork assembly, formwork removal, formwork arrangement, and formwork transportation. Of which the formwork leader and construction company would conduct communications and negotiations. After work completion they will be transported and be used at the next project or be stored in warehouse.

Lean formwork implementation process

The first tier, "Philosophy"

In order to continually improve the quality of formwork engineering the present research firstly defined the core value of formwork engineering, and applied Principle 1 for long term operations as the philosophy. Formwork engineering is one of the handcrafted merchandizes in construction engineering. It is a commercial product transformed from human labor resources including lofting, formwork processing, formwork assembly, formwork removal, formwork arrangement, and formwork transportation. Cultivating engineers would bring greater value for enterprises. It is important to shape engineers to fit the demands of the organization as well as supporting individual interests and benefits. In order for corporate culture to continue those engineers who implement the culture must be cultivated from within the company, and then the culture of continual work implementation quality improvements can become a part of corporate culture. This way every engineering and formwork supplier can help create quality and value under the same

culture for customers, society, communities, and their people.

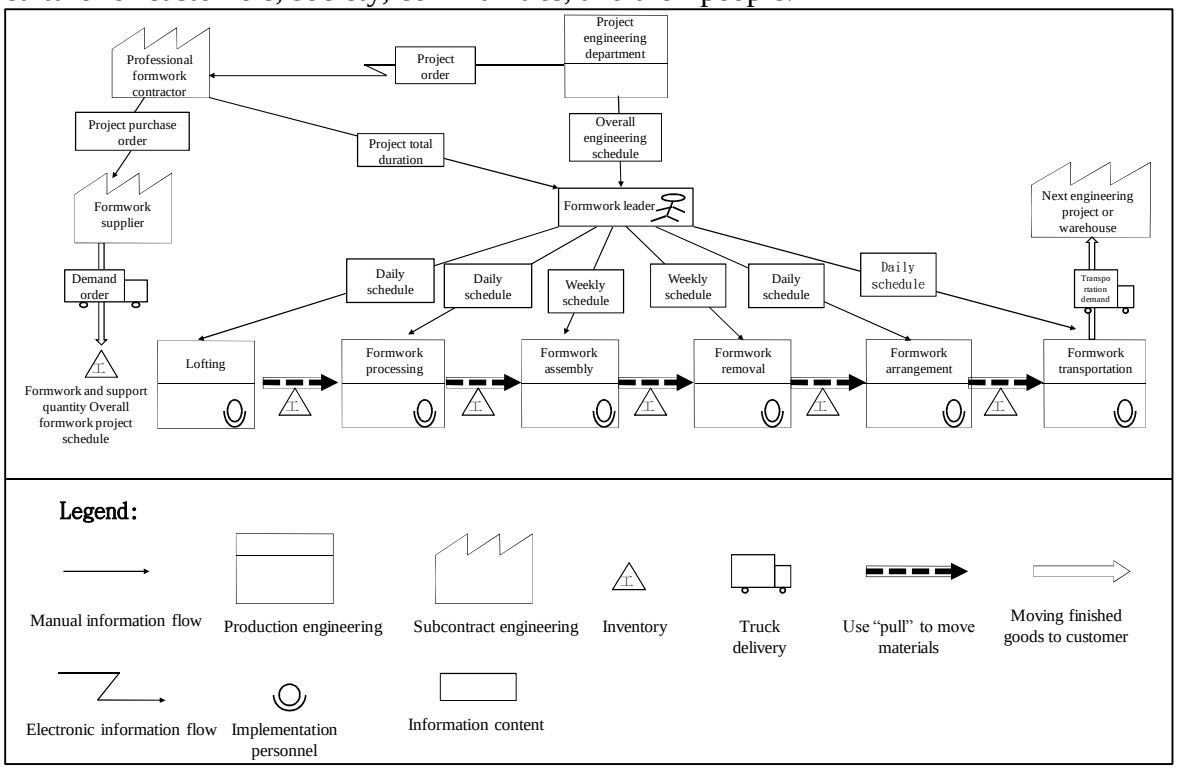

Figure 4. Current Formwork Value Stream Mapping

The second tier, "Process"

"Process" was defined in "The Toyota Way" as: Correct process will generate correct results. It indicated reduction in required time from materials to producing the final product will be beneficial in promoting the best quality, lowest cost, and shortest delivery lead time. The core value of this process was to eliminate waste. Formwork engineering value stream mapping was drafted by utilizing this concept to eliminate wasteful concepts and inspect the value of every step of work procedure. Waste generating problems were realized through the modern formwork value stream mapping, and improvements were made in an improved formwork engineering value map using principles 2 to 8 of "Process." As showing in Figure 5, by utilizing resources to support every production operation, and connecting every step of work implementation those unusual conditions that cause problems of work discontinuations were made to surface.

After the construction company forms a project engineering department, digital purchase orders are placed to professional formwork companies in advance. According to implementation advancement schedule the formwork assembly workload are evenly distributed so the work load would reach a certain level of stability, or the so called standardization (Heijunka); if the demands of the work implementation team fluctuates dramatically it would cause difficulties in adjusting work implementation team and resource. This would lead to waste and no standardization. Allow the formwork assembly date and implementation "pull" the measuring team to enter site and conduct lofting. Carry out lofting according to work implementation diagram. In terms of materials supply the formwork assembly purchasing demand quantity shall utilize the super market shopping operation model. The formwork assembly shall list out required dimensions to use the supermarket "1 per box" production board, and "pull" the demand for formwork assembly processing for production requirement of each formwork dimension. However, when

required to accommodate for the supporting motor electrical, steel bar, and concrete engineering, the scope of formwork shall include risk assessment of the individual supporting engineering works. After the assessments the formwork technical training and prior planning shall be enhanced. Framework processing is a predictable and highly repetitive operation, and its key units could be standardized. The fixed routinely repetitive value adding portions in the work could be authorized to the operation work to carry out analysis. Immediate reaction shall be taken during the progress if assembly or processing dimensions are found to be erroneous, and site engineers shall immediately to the site and carry out remedial measures. When formwork supply run insufficient the formwork supplier shall take watch boards from the formwork processing supermarket and deliver periodically. Meanwhile the formwork implementation team shall relay the watch board content to the professional formwork supplier and authorize formwork implementation team to carry out the demand receiving model. Utilizing the aforementioned method can keep the on-site framework quantities at minimal inventory. Comprehensive or special sized formwork are assembled or processed according to actual work implementation schedule. In terms of formwork removal it could be carried out according to building specifications of removal times for pillar, beam, and wall, as well as generating watch boards before or after concrete pouring. The queue card method or similar methods could be used to message the formwork implementation team to conduct formwork removal. For instance, the minimum removal time for pillar, beam, and wall without supporting side formwork is 12 hours. This means removal can take place 12 hours after pouring. If the building requires formwork assembly on a second floor, then take the removed formwork up to the next level and conduct assembly. If there is no next level for work implementation, then the removed formworks shall immediately be arranged and transported. They shall be transported to the next project by adopting the first in first out ordering method.

The implementation techniques can help the personnel to execute formwork operations according to standard operation procedures. The implementation techniques shall be used to support the workers and not replace them. In other words, formwork implementation procedure is far more important than implementation technique. The stability, reliability, and predictability of procedure are more important than using superior techniques. The formwork implementation team shall carefully avoid decisions that were not common acknowledged by the team during implementation procedures, processing procedures, or supply chain procedures.

The third tier, "People and partners"

"People and partners" utilized management principles 9 to 11, and their core values are the respect for team work, nurturing superior on-site engineers and then assemble superior implementation teams. All implementation regulations are for supporting the team to carry out the job of value creation. The actual value creators are not the team, but the on-site engineers. The primary purpose of team task coordination is to encourage the on-site engineers and promote mutual learning between them. Balance should be established between individual superiority and team performance. A superior team can only be put together with superior individual on-site engineers. A team should be formed by training suitable on-site engineers and combine them with professional formwork teams.

Traditional construction companies tend to subcontract to professional formwork companies at lower prices which resulted in mixed qualities of formwork used by formwork vendors. If the formwork cannot support the liquid during concrete pouring then the formwork will release energy and explode. Therefore market prices must be researched before subcontracting to professional formwork companies. Subcontracting shall be

evaluated and conducted carefully in order to allow formwork suppliers to take quality into account. Construction companies and formwork suppliers should learn under standardized implementation procedures. During which the procedure, quality, and price shall all be discussed. The ultimate goal is the development of the construction company and formwork vendor into extended business partners.

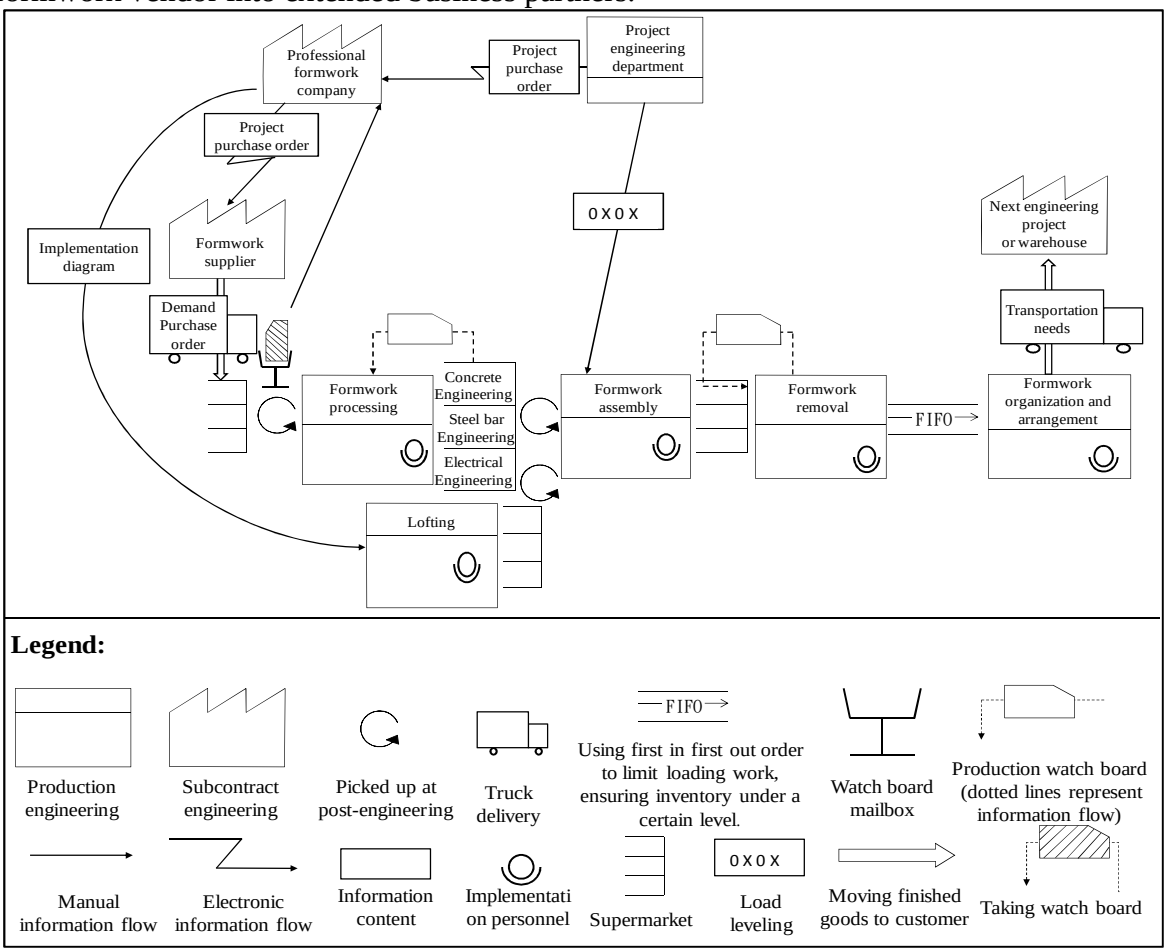

Figure 5. Improved Formwork Value Stream Mapping

The fourth tier, "problem solving"

The present research established value stream mapping for problem solving and continual improvements. Management principles 12 to 14 were utilized for effective adjustment and accommodation for formwork engineering. It is important to investigate the root causes of problems with objectivity. Personal visits to examine actual operational procedures in detail are beneficial for judging and solving problems. It is also important to cut into the causal chain of the "root of problem" rather than become trapped within "problem understanding." For example: construction company reducing subcontracting bid price that influence the formwork implementation quality and attitude. Consequently, in order for traditional construction companies to lower operational cost they are no longer willing on extra expenditure costs that enhance implementation technique and management skills. Therefore formwork implementation qualities are constantly subpar, and the root problem came from the subcontract bidding price set by the construction company.

It is important that traditional construction companies make organizational changes so they become learning organizations. In addition, construction companies and formwork companies shall discuss problems and problem solving solutions within the value stream

mapping. The opinions of formwork companies shall be collected and solution consensus shall be reach.

Conclusion

The present research made detailed discussions on the Toyota Way and 14 management principles. They were applied to formwork engineering. The Toyota Way and its 14 management principles carried 75 years of history with the concept of training and nurturing its personnel and continual learning attitude as its core philosophy. It is suggested the long term operation and waste elimination concepts can be learned from the Toyota Way. By implementing these concepts there can be new opportunities for the construction industry. The present research applied the Toyota Way to improvement formwork engineering, and established an improved formwork value stream mapping to reduce waste during formwork implementation, as well as adding operational value. In terms of long term concepts, it provides the individual, team, and partners with a continuous improvement and learning platform for growth. A new philosophy was introduced to improve formwork engineering.

It would be more interesting to show a case study to validate the effect of applying the Toyota Way for Improving Formwork engineering, and show some feedback from various teams involved in this improved workflow: what they like, what they don't like, what they are the benefits, and what they are the difficulties or limitations, etc.

References

Construction and Planning Agency Ministry of the Interior. (CPAMI). 2008. Construction industry Economic Overview 2008.

Han, T. 2000. Pushing the modernization of Taiwan: Chiang. Times Press.

Council for Economic Planning Executive Yuan. 2004. New Ten Major Construction Projects . Executive Yuan Council for Economic Planning.

Directorate-General of Budget Accounting and Statistics. (DGBAS). 2009. domestic production and trade deflator (NT million) -. Republic of China Statistical Information Network, web site. Available from: http://www1.stat.gov.tw/mp.asp?mp = 3.

Li, Hongsheng and Yang, Ching-Chow. 2009. Elaborating on the Toyota Production System. Quality Digest. No. 45, 3.

Dong, Wenhai. 2009. Toyota: Master of Crisis. ENTERPRISE MANAGEMENT. fifth.

Peng, Yunhong. 1991. Construction Project Energy in Taiwan Survey and Analysis. Ministry of the Interior ABRI.

Peng, Yunhong. 1992. Construction Project Energy in Taiwan Survey and Analysis 2. Ministry of the Interior ABRI.

Liker Jeffrey K. 2003. The Toyota Way. McGraw Hill.

Taiichi Ohno. translated by Kwok Rei Association TPS independent Research Council. 2004. Toyota Production System. Chungwei Development Center Foundation.

Song, Rui-lun. 2008. Investigations on Construction Formwork Engineering Contracting Strategy. master's thesis. Feng Chia University. Department of Civil Engineering.

Chang, Hongchan. 2007. Collective Residential Housing Architectural Formwork Productivity Analysis. master thesis. Institute of Civil Engineering. National Taiwan University.

Zhuo, Liyan and Yang, Zhibin. 2004. Problems of New Domestic Formwork Construction Methods. Modern Construction. 293. pages 31-36.

Shen, Jinfa. 1992. Formwork Engineering.

Lai, Shihpao. 1991. Production / Operations Management - Essentials and Cases. Hwatai Publication House.