INTEGRATED FRAMEWORK FOR PRODUCTIVITY IMPROVEMENT: ACTION RESEARCH APPROACH WITH LEAN CONSTRUCTION THEORY

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ABSTRACT: Lean construction theory is universally being applied in many actual projects for productivity improvement and process innovation. Most of proposed lean approaches, however, could not guide an actual implementation to the level of expected improvement, largely due to their inapplicability under in-situ circumstances. To reduce the gap between the theoretical approach and practical application, this paper suggests an action research approach integrated with lean construction theory to provide more practical solutions in a real setting. The results of a pilot case study showed that productivity was almost doubled than before applying proposed approach. Effectiveness of this framework will be further validated through applying to more broad case applications.

Keywords*: Lean Construction, Action Research, Practical Productivity Improvement, Integrated Framework*

1. INTRODUCTION

Over the last few decades quite a number of researches have investigated Lean Construction to achieve the productivity improvement in construction projects and with many case studies, these researches have shown that Lean Construction theory could give a positive effect to the improvement of productivity performance [8], [18], [20].

On the contrary to such academic research achievements, little or rather decreasing improvement of productivity in construction projects was reported in the real industry since 1960s [14]. The fact clearly represents that any effort in the academic fields to apply Lean Construction theory towards productivity improvement was put lacking in proper consideration of the relevance between the effort and the practical outcome of the real industry [15], [16].

This study is to present Action Research (AR), active and cooperative research method between a researcher and a practitioner, as a solution for the known problem. As a methodology for the solution is not only based on researcher's academic backgrounds but also is on the practitioner's experience, AR mainly focuses on the objective, or suggesting the practical breakthrough. From the combination of the analytical aspect of Lean Construction and the practical view of AR as applying AR and Lean Construction together, we could figure out how to make the previous productivity-related study more effective as the real industry.

2. LEAN CONSTRUCTION THEORY AND PRACTICES

Lean construction, as a representative of productivity improvement theory in construction management field, has an objective targeting on maximizing the amount of value with minimizing the waste of input value [3], [8]. In order to achieve this goal many researchers have developed various lean techniques or tools and have applied them into a wider range of construction processes [19]. However, their efforts did not turn out to be much helpful for industrial practitioners [21], and more often than not, the efforts were not actually delivered to industrial practices [21].

The underlying causes for this disconnectivity can be categorized into the three parts. First of all, studying without the actual participation ratio of practitioners can do matter. Many lean construction studies investigated the production system, designed the productivity improvement plan, and validated the result from actual projects. A large part of these studies, however, has just proceeded in the academic view only; in other words, they kept practitioners away from participating in a research to take on a role investigating/analyzing the details of actual project, which academics cannot easily figure out. This limitation thus made lean construction applications unable to realize industrial needs and be focused only on theoretical and conceptual issues [23].

A narrow view in navigating a construction process is the second reason. Construction process is usually a vast multifarious system and is composed of various individual sub-processes [6]. For such reason, a research on the improvement of production process is strongly required to take a holistic view of whole production system, which in turn enables to investigate various aspects of the construction process with considering such multiple dimensions as cost, time, workability and even social factors in the same line [16]. However, most of the conventional lean construction researches only considered productivity improvement and easily ignored the other changes affected by the productivity improvement plan. The biased point of view can readily result in lean studies impractical.

The final criticism of the disconnectivity is the lack of feedbacks from lean studies to practices. The effort to improve a specific case by applying lean theory is usually confined to a single approach. In other words, both the experience and the knowledge captured from lean-applied case studies are occasionally unable to be transferable to other cases for additional improvement. This cutoff restricted lean theory to fragmented, temporary and impractical approach.

In short, the gap between the lean theory and practices is becoming widening due to the aforementioned inherent causes. For further enhancing the lean construction theory, the effort to bridge the gap is highly required.

3. ACTION RESEARCH APPROACH

AR approach which is practical research method based on theoretical knowledge can be an answer to narrow the gap. AR can suggest a practical solution to actual problems and provide interpretation based on researcher's experience; thus, it can be expressed as 'action & reflection' and 'theory & practice'. In other words, it refers to participatory research because it produces operational knowledge from experience and aims to interpret a new phenomenon based on this operational knowledge [17].

In contrast to existing research, which is typically conducted by professors or academics only, AR is conducted by academics and site members together, and it is conducted in less constricted circumstances [11]. In addition, active interaction between internal participants is well achieved in AR, while existing types of research are not [13]. Therefore, AR can be defined as a research method that allows integration of the researcher's 'research interest' and the practitioner's 'problem-solving interest' [12].

There are, however, some arguments that this characteristic is similar to consulting business in the way that it pursues improvements in the process through cooperation with practitioners [21]. However, AR is definitely based on scientific prospects, and the difference between AR and corporate consulting can be illustrated by pointing out that anyone who can help with knowledge management can participate [7], [9]. This is necessary to establish the organization's internal and external influences and various assumptions, to the extent that objective facts for the research such as academic knowledge and assumptions are thoroughly built. It also requires continual participation and repetitive experiments [1].

AR basically proceeds through a five-level circulatory process [17]. Details of this process are given below (Details were adjusted and arranged by collating [2], [17], [21]).

Step 1: Diagnosing. The current situation is analyzed to identify all problems that can be derived. Overall interpretation is necessary without reducing or simplifying complex situations.

Step 2: Action planning. The problems defined in Step 1 are organized and aggregated, and plans to mitigate or solve major problems are established.
Step 3: Action taking. The researcher and practitioner cooperate to apply the established plan. Theoretical hypotheses and practical knowledge should be applied.
Step 4: Evaluating. When application of the plan is complete, the researcher and practitioner evaluate the results together. A critical assessment of the results and analysis of the failures are conducted.
Step 5: Specifying learning. The accumulated knowledge from the action research is divided into the accumulation of new practical knowledge, the provision of a foundation for future action research from experience, and the accumulation of scientific knowledge.

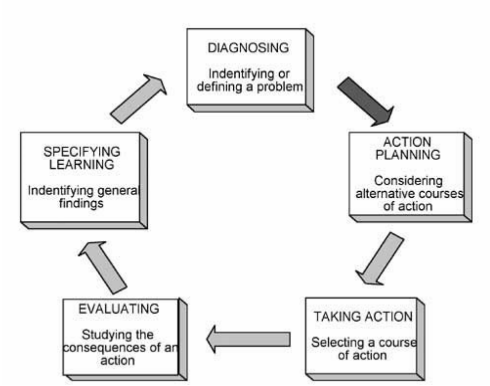

Fig. 1 Five steps action research process [17]

The merits of AR as observed through these processes can be summarized as shown below [4], [21]. First, AR assists in understanding the immediate problem situation in a realistic manner because it analyzes the actual operational process and derives the problems based on an understanding of the organization's characteristics. Second, AR assists both practical problem solving and scientific knowledge because the assumptions are established after observation of the problem situation. Third, AR assists with cooperation and improves performance because the researcher and practitioner can supplement each other's shortcomings through their own strengths and experience. Finally, AR aims for problem identification and solution with an overall view of the process, thus assisting in understanding the transformation course of the system.

In other words, based on the experience and knowledge of practitioners, AR can provide a holistic view of the process by showing the 'How and Why' factors, which are difficult to comprehend from a statistical or mathematical approach [21]. It is also possible to review the process and derive improvement methods under practical natural settings, making it easier to apply in practice [5]. However, it is limited in that AR can be conducted only as qualitative research by concentrating on practitioner participation and field applications. It is also challenging to generalize, as the problem-solving process is specified for specific cases [5]. Therefore, a research framework that can maintain the merits of AR while applying straightforward lean theory to practice is essential in this type of research scheme.

4. ACTION RESEARCH BASED LEAN APPROACH FRAMEWORK

As stated, AR can supplement the limitations of a lean approach to proceed with more practical research and moreover achieve greater productivity improvements. This research derives an integrated method to apply lean theory based on the five basic steps of AR process (see Fig. 2).
To improve the operational process through lean theory, it is important to define and specify the current problems [17]. In AR, this is achieved in the diagnosing and action-planning stages, and the process improvement methods derived from these steps are applied in reality by the action-taking stage. The results are then assessed in the evaluation stage. General types of lean approach research proceed from the above diagnosing stage to the evaluation stage. However, the lean approach through AR also includes a specifying learning stage. The specifying learning stage is a stage in which the defined, developed and applied lean approach results are to be generalized into general knowledge. Based on this, the process resembles a holistic view. This stage not only provides a lesson from the lean approach to participants, but it also suggests process improvement objectives and a wider view as a stage preceding the diagnosing stage of future action research approaches. The tasks that take place in each AR stage are presented in details as below.

Step 1: Diagnosing

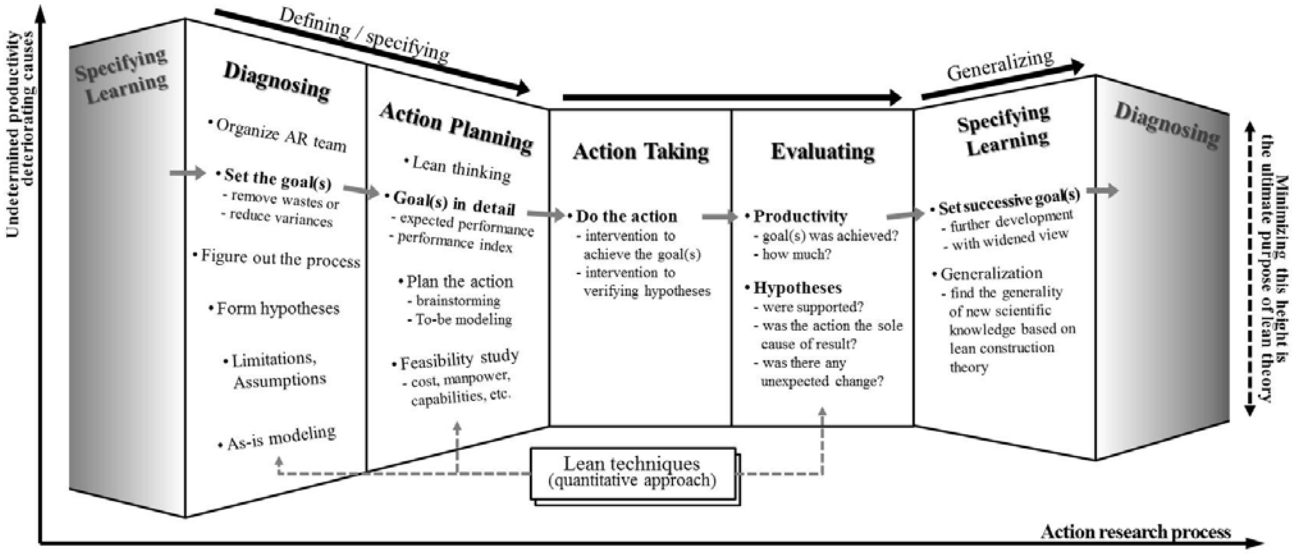

Fig. 2 AR based Lean approach framework

AR starts with organizing an action research team consisting of researchers and practitioners. Here, the researchers should fully understand the overall organizational process as well as backgrounds of lean theory, and the practitioners should be in charge of the operational details of a given project and be able to monitor the process.

It is important in the diagnosing stage to establish the purpose of the research. For productivity improvement, which is the main purpose of lean theory, goals need to be established regarding whether to remove waste, reduce variability, or pursue both. The current situation of the process and problem areas then need to be thoroughly understood. For this purpose, an influence diagram can be utilized. An influence diagram is a method that facilitates understanding of how process outcomes are determined by visually comprising the major factors that influence the process outcomes [22]. Through this, the basic assumptions and restrictions of the research issue can be assembled.

After understanding the current situation, problems, assumptions and restrictions of the process, Value Streaming Mapping and computer simulation can be utilized. VSM is a technique that apprehends each activity of the organization into Value Added Activity or Non-Value Added Activity and specifies the value for each activity [10]. The Current State Map can be composed from this, and the factors being wasted in the current process can be identified. On the other hand, computer simulation helps to understand problems in the current situation by widely reflecting and modeling factors such as the process situation and restrictions [23].

Step 2: Action planning

In this stage, cooperation between the researcher and practitioner is vital to derive the methods to improve the process based on ‘lean thinking’ theory. In this stage, it is necessary for more detailed establishment of the research goals presented in the previous diagnosing stage. This is achieved by selecting the type of outcome that needs improvement, the desired level of improvement, and the indicators to measure this improvement.

The improvement methods are then developed through brainstorming and discussion within the action research team. The suitability and target level of the proposed improvement method can be investigated by adjusting the current state value stream map used in the diagnosing stage as well as by using an as-is simulation model. The action research team also needs to examine whether the proposed improvement method is feasible in terms of cost, time, additional resource availability, and other constraints on a job-site.

Step 3: Action taking

This stage attempts to achieve the established goals through the process improvement methods developed in the previous stages. In this stage, it is important to manage the action so that it is implemented as planned through integrated management of the process. However, due to the characteristics of AR integrated with the applied lean approach, the improvement process cannot be strictly controlled in contrast to other research methods. Thus, the main purpose of AR in this stage should be set to improve the process under natural settings with the mutual cooperation of researcher and practitioners [5].

Step 4: Evaluating

It is the stage where the outcomes achieved in step 3 are reviewed from various angles. Similar to the general lean approach, this stage examines the improvements in productivity as well as whether the assumptions established in the previous stages have been verified. In addition, this step examines whether the improved performance resulted solely from the applied action and if there were any unexpected changes that were not foreseen in the action planning stage.

Step 5: Specifying learning

In the last stage, the comprehended results from the evaluating stage are generalized and organized into new knowledge so that it can be utilized or repeated in other processes or in follow-up action research. To this end, additional goals to improve the process even better is to be suggested based on the action taken and a more holistic view of the process can be achieved based on the various performance-related factors identified during the evaluation stage.

5. Illustrative case application

The AR case study was performed on a U-girder pre-fabrication and installation process for a light-rail transit construction site around the Seoul metropolitan area in Korea. This project is to build a light-weight railway with features of 18.4km in length and 42 months of duration. The project cost reached approximately 0.7 billion USD. The urban location of the site meant that there was little leeway in the way of material storage areas. Yet, the project kept U-Girders produced in the temporary plant more than a few weeks and installation of U-girder products were often queued for over a week. The resulting disconnection of the site severely impaired the productivity of the project, due to excessive buffers, change orders, re-handling, loss of materials, and associated costs. Interviews with the project manager committee revealed that U-girder pre-fabrication and installation was the crucial process but lots of problems were concerned to finish this project within the given duration. This is the reason of why the productivity and process improvements of this process are imperative and we performed the AR to finish this project within a very tight and limited schedule.

Step 1. First of all, we organized the team for AR who can control the whole project process. AR members should comprehend the purpose of AR process and come to consensus in order to reach the main goal. We then performed construction process analysis focused on the target process, “U-girder pre-fabrication and installation”. Through this analysis, we identified four major problems as follows; 1) trial and error in initial stage activity caused by lack of experience and reliable plan, 2) increase in production cycle time of U-girder, 3) delay of U-girder installation caused by late completion of preceding activities, and 4) lack of reliability and collaboration between upstream and downstream activities on job-site. After the problems being identified, simplified as-is model was developed to understand the current state of process.

Step 2. To make improvements, several assumptions were made; 1) separating the U-girders production from its downstream and adding more production capacity can lead to performance enhancement and avoid the interference by gaining the advantages of little’s law and decoupling theory; 2) reliability improvements can lead to stable flow of production by using shielding method; 3) high level of variability in the process can be stabilized by applying optimal buffer size. Then we finalized the action plans as to make additional production lines in temporary plant, modify a schedule plan process, and make additional storage area for U-girders to increase the buffer flexibility. After development of all action plans, we performed the validation test in order to confirm the applicability including location selection and investment cost analysis.

Step 3. Iterative action takings were performed when all of predecessors had been completed. The first monitoring was performed from January 20th (2007) (which was the completion date of additional capacity in the temporary plant and inventory storage area) to February 16th (2007). Based on the 1^{st} application, problems were found, for example, the capacity of U-girder storage area was 30 units at the maximum, but this area was overcrowded due to over-production. The 2^{nd} monitoring was performed again until December 9th (2007) to assure that the capacity increase and reliability improvement were properly implemented.

Step 4. Comparison was made between before and after applying AR approach integrated with lean theory. Approximately, the productivity performance was doubled (U-girder installing quantity per month increased from 15 units to 30 units). In addition, we noticed that interference or change rate between predecessors and successors in U-girder process was significantly decreased.

Step 5. Finally, we performed focus group interviews to identify the lessons and learned from AR based lean. Ten practitioners were mostly satisfied with the results of applying theoretical lean knowledge to obtain productivity improvements on job-site. Also academic researchers were content with practical verification of the processes and action plans. But, there were some limitations, for example, the lack of knowledge toward theoretical background and method of the practitioner has caused him to pose passive attitude. And simulation's usability can also be doubtful due to the requirement for detailed data and its complex process. So to make the AR based lean to become general practice in construction, these limitations should be overcome by providing appropriate training to practitioners and innovating AR processes.

6. Conclusions

This paper aimed to propose the research framework to promote collaboration between practitioners and academic researchers. So, this paper developed a framework in which lean theory can be put into practical experiences through an AR approach. This framework is significant in that it can improve the existing lean approach and make it more practical and proactive while accumulating the results of the applied action into new knowledge. The proposed framework is verified by case application. Case application results show the effectiveness of AR based lean approach as the productivity performance has been doubled compared to the current practice. But case study also shows some limitations in applying the framework, such as practitioner's passive attitude and difficulty of simulation. It has to be modified and innovated to improve the framework.

Nevertheless, through repetition of action research, the researcher and practitioner can attain a more holistic view and on this basis work towards reducing waste and variance. This is a result of the main characteristics of action research; participation of practitioners and phased progress through the Plan-Action-Feedback process. So, more broad case applications will be performed to validate the proposed framework in future research.

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