ASSIGNMENT BUFFER CONTROL FOR CONSTRUCTION PROJECTS

Jeongki, Kim
Dept. of Architecture
Seoul National University
39-dong 426-ho Seoul National University, Sillim-dong
Kwanak-gu Seoul, Korea, 151-742
kjk0305@gmail.com

Hyunsoo, Lee
Dept. of Architecture
Seoul National University
39-dong 430-ho Seoul National University, Sillim-dong
Kwanak-gu Seoul, Korea, 151-742
hyunslee@snu.ac.kr

Moonseo, Park
Dept. of Architecture
Seoul National University
39-dong 433-ho Seoul National University, Sillim-dong
Kwanak-gu Seoul, Korea, 151-742
mspark@snu.ac.kr

Hanguk, Ryu
Dept. of Architecture
Seoul National University
39-dong 426-ho Seoul National University, Sillim-dong
Kwanak-gu Seoul, Korea, 151-742
hglyu@cric.ac.kr

Abstract: Buffer in construction management means a cushion that protects the planned project schedule from uncertainty. Traditional buffer management, however, often fails to perform its purpose, hence reducing efficiency in schedule management. Such failure has been mainly attributed to the fact that traditional buffering is based on experience rather than being made in a systemic manner. For this reason, in this paper, we investigate the inefficiencies of the traditional buffer, especially focusing on the manager's assignments. In this study, in-depth interviews were conducted on sixteen schedule experts in twelve companies in Korea to explore their scheduling practice, and interesting facts were found. By analyzing the interview results, this research identifies three fundamental problems of the traditional buffering, based on which, Assignment Buffer Control (ABC) is proposed. ABC improves the problem by metamorphosing the buffer and incorporating manager's assignment direction to the schedule.
Keywords: Buffering, Scheduling, Uncertainty, Manager's Assignment

1. INTRODUCTION

Buffer in construction management means a cushion that protects the planned project schedule from uncertainty. For a long time, buffering has been a common practice in construction. Schedulers normally add additional time to the estimated schedule to ensure to cover up for any uncertainty that may occur during the planned schedule. But, there is no rule as to how much time should be added, who should make the buffer and how to manage buffer. In other words, traditional buffering has rarely been managed in a systemic manner. As a result, traditional buffer management has often failed to perform its intended purpose of buffering. To make matters worse, it sometimes has adverse effects, hence resulting in the inadequacy of buffer placing and sizing [Park and Pena-Mora, 2004].

For this reason, buffer management as become recognized as one of the important keys that need to be solved. Previous researchers have emphasized that traditional schedulers fail to divide the planned schedule into the buffer and the activity duration, hence resulting in ineffectiveness. Although it is recognized that a more effective method is needed to manage a buffer and researchers have tried to establish conceptual buffering frameworks, there is still no practical buffering strategy that can be applied to managers who actually use a schedule for ordering the construction works.

To address this issue, we suggest 'assignment buffer control', a practical buffering strategic for field managers. Through in-depth interviews with experts, we found an important concept that buffer must be metamorphosed along the project life cycle. In addition, buffer has to be distinguished from activity durations. Using these results, we suppose an alarm type buffer for managers in executing phase. The research results indicate that assignment buffer control (ABC) can help achieve a robust schedule performance by clear direction and enough time to meet manager's important assignments.

1.1 Previous Buffer Theory

Current researchers consider that the traditional way causes ineffective management and have recognized the need for a more effective method to manage buffer. [Goldratt, 1997] researched into the how wasted buffer, which be is normally made by scheduler's mental process, is generated. He argued that buffer should be put in front of the critical activities and schedule can be measured by buffer consumption. [Ballard and Howell, 1998] suggested that 'PPC', a tool of productivity measurement, is useful for increasing productivity at the production unit that uses buffer. [Chua et al. 2003] embodied 'integrated Production Scheduler' that uses four kinds of buffer area which was intended to protect work resource and information from uncertainty. [Park and Pena-Mora, 2004] suggested 'Reliability Buffering', aimed to generate a robust construction plan against uncertainties and examine the effectiveness of reliability buffering by system dynamics models.

However, despite their contribution, there is not any trial to change the attribution of buffer along the project life cycle and to point to the manager's informal patterns which is commonly generated in many projects.

2. BUFFER MANAGEMENT IN PRACTICE

Observing the practical field manager at work, we observed that they are sometimes not restricted by their schedule manuals or text book which defines the schedule process and the form. In fact, managers use the schedule manual or the scheduling form only to make the performance report in many cases. In this study, from these practical scheduling patterns of view, we will devote some space to the discussion of the real buffering process in the field. Although managers have not been using systemic tools for buffering, they have had their own ways, and thus it is necessary to analyze their hidden buffering mechanism for building the systemic and useful buffering tools.

2.1 Interview with Experts

This paper deals with subjects about hidden mechanism, how to manage the project schedule and why the project be delayed. Because they are informal opinions or secret information, they, generally, are not apt to state the hidden mechanism to others. To know what is the problem of current schedule management which happens under construction, methodology based on in-depth interviews are useful for investigating technical aspects of contemporary phenomenon with real life context, when the boundaries between phenomenon and context are unclear or there are multiple sources of evidence are used [Yin 1989, p.3]. Yin (1989) also suggested that multiple cases should be regarded as multiple experiments and not multiple respondents in a survey, and so replication logic and not sampling logic should be used for multiple case studies.

Table 1: In-Depth Interview Main Contents

Process	Main contents for in-depth interview
Scheduling process (Manual and reality)	Total project duration and Activity duration Milestone, detail schedule and working schedule Precedence relationship Scheduling method decision
Schedule control process (Manual and reality)	Total project duration and Activity duration control Making working schedule Adjusting schedule conflicts Task management
Schedule updating & reporting (Manual and reality)	Schedule updating Making schedule report Management of as-built data Applying the data in next project

In a resulting this research, we got the data about scheduling process, management process, and their mechanism from sixteen experts, who have worked over five years, in twelve companies in Korea. Each expert hasn't worked together but has different experience of construction schedule management. Three aspects as depicted Table 1 are considered in the In-Depth interviews.

From this interview, we found out that schedulers tend to perform schedule management in their own ways and not follow the manual. They only used the manual when they had to report. This problem will be discussed in detail in the next section on the current scheduling process and problems.

2.2 Current Scheduling Process and Problems

There are still fundamental problems in current scheduling process in construction even if many researchers have tried to make optimal scheduling process for a long time. It is essential to understand how schedule is actually made or managed by field managers in order to find what kind of problems exists. As it was very difficult to get raw information from respondents, we held an in-depth interview with each expert. We observed some special behavior patterns shared by a majority of the respondents as summarized in Table 2.

Through in-depth interview, we found three main problems. Results 1, 2, and 3 show that there is generally sufficient time to perform the project in a majority of the construction projects. Results 4 and 5 show that there is insufficient information for the work or task to be done within the planned schedule. Lastly, results 6 and 7 relate to the unreliable feedback data in the as-built schedule. The reasons and solutions of each problem will be discussed in section on Assignment buffering.

Table 2: The Main Results of In-Depth Interview

Main problems	Practical patterns about schedule
Sufficient time in schedule	1. Enough time to perform the project
	2. Having an informal schedule, cut the original schedule
	3. Trusting informal schedule more than formal schedule
Insufficient information in schedule	4. Using the calendar on the desk, not schedule
	5. Most importance of manager's ability in a success or fail
Unreliable feedback data in schedule	6. Each stores information in own somewhere
	7. Fabricated final performance report

3. PREMISES OF ASSIGNMENT BUFFERING

3.1 The Definition of Buffer

Buffer in construction management means a cushion that protects the planned project schedule from uncertainty. This cushion can be any forms, such as time, information, money, and so on, that can lessen the impact from uncertainty. This uncertainty is, also, defined as a state of doubt about the future in a schedule manner or about unknowns that, if it occurs, has a positive or a negative effect on schedule at least one project objective. So far, there have been a few researches done on the concept of buffer in the construction business, and moreover there is no proper definition of buffer. In this paper, we define buffer as all kind of cushions that protects schedule performance from delay or harm, and buffering means all kinds of acts to manage buffers.

3.2 Three Components of Buffer

1) *Buffer Type*

Buffer type is the form used to keep something. In various fields of industry, buffer has used in many kinds of forms. For example, traditional buffer type in construction is commonly time, stock is a buffer type in manufacturing, and memory may be a buffer type in computer engineering. Sometimes, a warehouse may be used as buffer. In traditional construction management, most schedulers and researchers consider time as the buffer type. Most of schedulers added enough time to protect the schedule and researchers have studied adding, removing, and adjusting the time as buffer. However, in this paper, buffer not only refers to the time, but also any cushion to protect schedule in this paper. For example, a scheduler may choose the type of time, cost, information, alarm, stock, space or other thing which can be created as buffer. By understanding the buffer type to have a wider meaning than the traditional ones, we can apply aggressive buffer management to various cases to achieve reliable schedule management.

In this paper, the forms of time and alarm are considered as the buffer types. Actually, time is the most appropriate and basic to be considered as buffer, but it is too passive to protect the construction project schedule. So, aggressive alarm buffer, which is intended to prevent human errors, is applied to complement and amplify time buffer.

2) *Buffer Location*

Buffer location is also an important element of buffer. Buffer can be located at the end of the activity, in the front of the activity, or in the middle of the activity, or even other space. Where the buffer, which is related to an activity, is located has a different effect in each case. For instance, in the traditional way, the buffer is put at the end of each activity. This often causes 'the last minute syndrome' [Park and Pena~Mora 2004, Goldratt, 1997]. [Park and Pena~Mora 2004] proved that reliability buffer which is located in the front of each activity generates a robust construction plan against uncertainties by simulating dynamic project model. Other researchers arrange the buffer about information and resource in fixed location regardless of the type of activity [Chua et al. 2001]. They argued that their buffering make it possible to achieve high productivity and continuous workflow. Therefore, deciding on buffer location is also another important consideration in buffering. Thus, in this paper, we applied the buffer in the front and at the end for reliable schedule execution.

3) *Buffer Size*

The last issue in buffering is how to size a buffer. This crucial issue has been studied extensively in the past as the traditional way of sizing a buffer has been the most important reasons for the ineffective schedule management in the past. In the traditional way of sizing the buffer, buffer is decided based on individual experience and assigned in a uniform way, and not based on reliable data or decided in a systemic method [Ballard and Howell 1995]. Goldratt [1997] explained three psychological factor about the traditional buffer sizing method in 'critical chain': the time based on a pessimistic experience, the time added safety factor in each management level, and the time estimated to protect estimations from a global cut. In order to improve the traditional way, Pena~Mora and Li [2001] suggested overlapping framework as buffer size determinants, which has the following characteristics: Production type, Reliability and Sensitivity. Chua et al. [2001] suggested Regular buffer size, where, for example, one week is for working buffer and the next week is for shielding buffer, in the calendar, and has nothing to do with activity, resource or information. As a matter of fact, buffer size is related to how much impact there are by uncertainty, and so buffer size is generally in direct proportion to uncertainty size. Therefore, buffer size must be decided by analyzing an activity through probable methods and using as-built data after fully understanding the uncertainty in the situation.

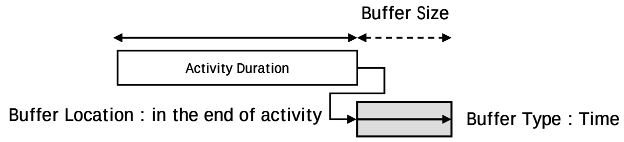

Figure 1: Three Components of Traditional Buffer

So far, we discussed three components of buffer. Figure 1 shows the concept of three components of buffer, and Table 3 presents the difference among the buffers in previous research.

Table 3: Comparison of Buffer Components

Components / Kind of buffer	Type/ Unit	Location	Size	Mean
Traditional Buffer	Time/ Time	In the end of activity	Fixed by parkinson's law	A cushion against uncertainty
Goldratt	Stock & Time/ Time	In the front of activity(stock) In the end of project(time)	Changeable until optimization continuously	A cushion against uncertainty Progress management tool
Chua et al.	Term /Time	In the calendar	Fixed by buffer definition	Weekly or monthly Task target
Park and Pena-Mora	Time/ Time	In the front of activity	Changeable by activity attribution	Checking and dealing time against uncertainty

3.3 Changeable Buffer Attribution

In assignment buffer control, the buffer type, location and size are changed based on the construction process. Initially fixed buffer size is not adapted in the construction system which changes continuously. A disadvantage of the traditional buffer location is the 'the last minute syndrome' and 'parkinson's law'. Lastly, the form of time is not efficient to make a reliability of precedence activity. As the construction process changes, the mean of the buffer must be changed appropriately as well. The main concept of Assignment buffering is that the attribution of the buffer must be changed to keep the schedule reliability effective.

3.4 Separating Buffer from Activity Duration

A buffer should be managed separately from activity duration. In the assignment buffer control, it is assumed that traditional activity duration is composed of three parts. One is the essential duration of activity which means parameter in statistics view. The second part is the deviation of activity, which means residual in statistics view, and the last part is the buffer of activity. For example, if we repeat an activity indefinitely and as a result the activity is frequently takes five days, the five days are the activity parameter, essential duration. Modal duration is defined as an essential duration because most frequency reflects the attribution of the activity. If half of the trials, which are limiting percentage, finish in six days, the residual is one day. In this case, the essential activity duration is subtracted from the mean of activity duration. The limiting percentage can be defined by the company's schedule policy (eg., 50%, 80%). In this paper, we assume that the limiting percentage is 50%, since we can judge whether the project is a success or failure in the schedule view by 50%. If an activity finishes in 50% of probability distribution, it can be regarded as showing a good performance. So far as concerned, the sum of an essential activity duration and activity residual is assumed as the activity duration and the excessive duration is considered as the activity buffer.

3.5 Manager's Errors

One of the most frequent errors that is observed in the traditional schedule method is due to the fact that managers do not have sufficient information. Managers need to plan what activities that need to be done and by when those activities need to be done. The managers give instructions to workers based on a schedule they make. But, in a complex construction project, it is impossible to do the complex task merely based on a traditional schedule which contains only simple timely and sequential information. So, in most cases, a manual is given to the managers, and it is very systemic. Even with this manual, however, managers often miss certain tasks, such as material and labor orders, the requirement of successor, from the hardness of matching the schedule and the manual which may consequently result in the difference of management ability among managers, and generates the schedule deviation between projects if scopes of projects are same each other.

In addition, the negative impact of manager's errors is critical to the project. [Josephson et al. 2002] investigated about the rework which causes time delays and additional costs to be incurred in the project. They pointed out that people's errors constitute a large portion of construction parts. Manager's errors, especially, causes the material and labor reworks, which despite the low rate of error's frequency consequently result in time delay and incurrence of additional costs,. [Love and Josephson, 2004] suggested the error chain to reduce failures, and found that the main reason why these error occurs is due to poor planning, lack of knowledge, experience of personnel, and lack of attention.

4. ASSIGNMENT BUFFER CONTROL

Many managers use the calendar or notes on their desk to make sure they avoid making scheduling mistakes even though a separate schedule is provided to them. Thus, is it good practice to integrate the schedule and manager's assignment to reduce manager's error. Clear directions and target can effectively shield production from flow uncertainty [Ballard and Howel, 1998], and repetitive alarms or reducing repetitions can improve the reliability of meeting deadlines.

For these reasons, we suggest ABC, assignment buffer control, which assures manager's important tasks instead of traditional timely buffer. It is an important function of the buffer to assure the duration of the processor, to give successor a sufficient preparing duration and to check the progress continuously, reducing the possibilities of manager's errors. Assignment buffer is a positive strategy compared with the tradition one with respect to handling uncertainty. Assignment buffer offers information and concrete directives to managers. Until now, previous information systems provide only the information, not directions. while ABC focus on the clear direction supply

4. 1 Case Model

Let us assume that manager is responsible for the stone masonry work which generally has three constraints as provided in the company's manual. One is that the order request for the stone must be made three months prior to the masonry work start day and the progress of the work must be checked from time to time. The second constraint is that labor preparation must be noticed after a special work; A task, and before three days and a day three times than work start day. The third constraint is that the work can start after the precedence: F to S relationship.

In the traditional way, managers rely on their own experience when considering constraints. If the manager does not have any experience on stone masonry work, the chances of failure is high. Specifically, the manager without any experience is more likely to order the stone too late. Since the schedule only has the timely information about activities, very few beginners actually look up the manual and do the task on time. After all, the management method is different among managers and differences in the manager's experience can be seen in their schedule deviation.

In the ABC view, the buffer automatically gives the managers concrete directives on the time to do the task which assures that the task is performed. The company's manual and the know-how of the required are integrated with the schedule as the assignment buffer. For example, when it is time to order the material and recruit workers or before, the metamorphic buffering system notes this task to managers, and managers engage communication with the stone supplier and order the stones. Even if there is a delay in the precedence, the task can be repeated because the buffer also moves task notice following the change of the schedule and alarm it again. In other words, the buffer reduces the deviation by the manager's manageable ability by experience difference and increase the reliability of activity. As a result, successor is assured of less uncertainty from the precedence result.

4.2 Three Component of Assignment Buffer

For effective controlling of the assignment buffer, the type of the buffer should be the alarm type, the information and directive given to managers such as checking labor, sample order and requesting detail drawing. All of the tasks of the manager need not be clearly defined in the assignment buffer. Since the main function of the buffer is to protect the activity from uncertainty, the buffer must contain only the important task required to keep the schedule on track. For example, the critical chain and critical relation must be protected by the checking the requirement for activity and agreement about duration for preparation with the supplier.

The location of the buffer should naturally be in the beginning of the activity. In the executing process, it is much more critical to give successor a reliable precedence than to worry about delays that still do not arise. In the executing phase, it means that the location of buffer has to move from the end of the project in the contract buffer to the front of each activity.

Lastly, the buffer size in the assignment buffer means the duration from the alarm to the activity or work related with the schedule, material, labor and information. How to size a buffer is an important issue in buffering. ABC refers three resources for reflecting the reality and demonstrating the responsibility from co-works; the supplier's opinion and agreement, duration database and manager's opinion.

4.3 Pushing Signal and Pulling Signal

For sizing and locating the buffer, a standard point is needed. Standard points include the activity starting point, specific work finishing point of the precedence, or specific work starting point of the precedence. In this paper, we considered two kinds of signals, *Pulling Signal* and *Pushing Signal*. As the assignment buffer is activated by the signals, *pulling signal* means the sign by the target activity, and *pushing signal* means the sigh by the precedence. Table 4 and Figure 2 show the relation between these signals and alarm location and size. Generally, pulling buffer is used in the cases where the requirement is dependent on the external factor, such as imported material and complex sub-deliverable. Most of them require some time to make or prepare. Therefore, the buffer size must be estimated on the basis of the target work starting point. Meanwhile, pushing buffer is used in the cases where the requirement of the target work is dependent on the precedence. For example, a manager must meet the target activity foreman before finishing the precedence work for the 5th floor of a 20 floor apartment construction project. In this case, the basis of the pushing buffer basis is the point at which time the precedence work of the 5th floor is finished. Pushing buffer is often applied to the expectable work and experienced work.

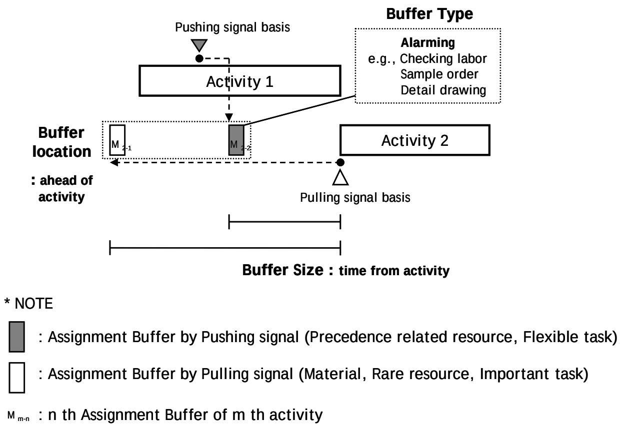

Figure 2: Pushing Signal and Pulling Signal

4.4 ABC Process

For controlling the buffer in the executing stage, a manager must consider when the work will be finished and what needs to be done to complete it. Actually, schedulers take into consideration the opinions and expectations of its co-worker before a work is started because they want to reflect the reliable condition and the real ability of its team. From our in-depth interview, respondents pointed that they tended to complete they work on time when the target duration is agreed with the co-worker. Meanwhile, managers are apt to set the target duration for finishing their work too short. This is because co-workers frequently suggest time in excess to finish the work. However, the manager's arbitrary setting of duration can be too short as co-workers generally have a more accurate judgment on the duration. In addressing this issue, ABC uses the duration database, which does not contain the devoted buffer, for deciding the work duration. As compared to three durations; manager's opinion, co-worker's proposal and the mode of the activity duration E_i in the database, the agreed duration with foreman and manager is defined as the target duration in the formal schedule in the executing stage. In other words, the activity target duration is decided immediately before the activity starts, and durations of successors in schedule are considered as the mode E_i of the duration database until successor will start or be dealt with.

With respect to preparing the works to be assigned, managers should also take into consideration the opinions of its co-workers. Managers must provide enough time and timely information for reliable work duration. As stated in the second metamorphic buffer; assignment buffer, the type of buffer ensures that enough alarm time is given to the co-worker.

In summary, the assignment buffer control focuses on removing useless time buffer, increasing the reliability of the schedule made by manager, co-worker and duration database under low uncertainty.

With the traditional buffering approach, delays in the predecessor activity are directly passed on to the successor activity by simply pushing forward the initially planned buffer and successor activity, as depicted in Figure 3-(a). Moreover, other relative activities should be delayed even though there is a possibility that the activity can be finished earlier as demonstrated in activity 3 in Figure 3-(a). In contrast, the metamorphic buffering is only applied to the essential activity duration which excludes the traditional time buffer (B_i). While, the traditional time buffer (B_i) is changed into the second metamorphic buffer (M_{i-n}). As a result, the buffer (t_6-t_4) of activity A is removed, and activity B can be commenced at t_4. In the case of activity C the work can also be finished at t_3, and indirect cost may be lower than the traditional one.

In case where the actual duration of the predecessor activity is longer or shorter than its initial duration, metamorphic buffer informs the successor of this fact. For instance, in Figure 3-(a) and 3-(b), by applying the assignment buffer control, the initial predecessor activity duration (D_i) is updated at time 't_c' with the forecasted duration (D_f), based on which assignment buffers M_{i-n} is also newly decided by changing the signal basis. If the schedule is delayed, each signal basis is also changed. M_{B-2} in Figure 3-(a) is changed by the shortened schedule to M_{B-2} in Figure 3-(b), since the pushing signal basis SB_{A-2} in figure jumped ahead. Therefore, managers and co-workers can perform their tasks well although the schedule is delayed or shortened, and the activity duration becomes reliable.

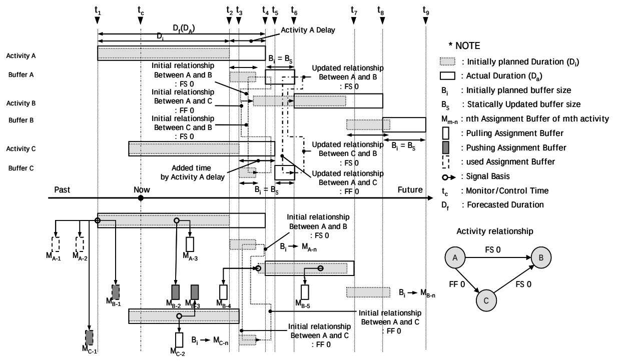

Figure 3-(a): Assignment Buffer Control Ⅰ

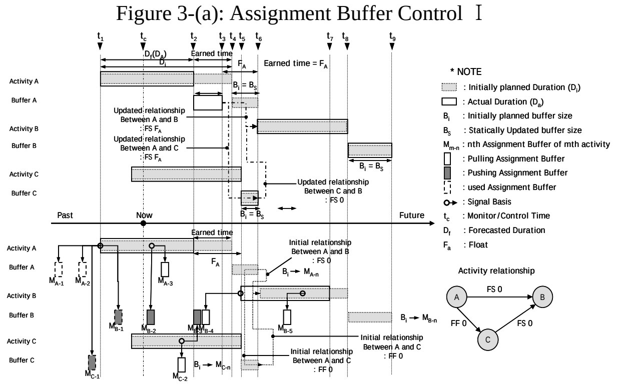

Figure 3-(b): Assignment Buffer Control Ⅱ

5. CONCLUTION

The traditional contingency buffer in construction projects has so far been used is a non-systemic and informal manner. As a result, there have been significant schedule variations among similar projects, and the learning effect by the feedback was low. The schedule subordination, the insufficient information on schedule and unreliable feedback data were found to be the critical causes for the ineffectiveness of the traditional schedule management. The in-depth interview with sixteen experts of twelve companies in Korea gave us some valuable information about buffering and scheduling in real practice which cannot be found in manuals. Based on these result, this paper presented assignment buffer control (ABC), which is aimed to formalize the informal methods of managers and to provide actual assistance to managers. ABC was suggested to improve the effectiveness of buffering, and help reduce the total project duration and at the same time enhance reliability of the activity. The proposed ABC in this paper is expected to impact both the academic field and the construction industry.

REFERENCES

[1] Al-Monami, A. H. (2000). "Construction delay: a quantitative analysis." Int. J. Proj. Manage., 18, 51-59.
[2] Ballard, G. (2000). "Phase Scheduling." LCI White Paper, 7.
[3] Ballard, G., and Howell, G. (1998). "Shielding production: Essential step in production control." J. Constr. Eng. Manage., 124(1), 11-17.
[4] Ballard, G. (2000). "The Last Planner System of Production Control." Doctoral Thesis, School of Civil engineering, The University of Birmingham.
[5] Chua, D., Shen, L., and Bok, S. (2003). "Constraint-Based Planning with Integrated Production Scheduler over Internet." J. Constr. Eng. Manage., 129(3), 293-301.
[6] Chua, D., and Shen, L. (2005). "Key Constraints Analysis with Integrated Production Scheduler." J. Constr. Eng. Manage., 131(7), 753-764.
[7] Goldratt, E. (1997), Critical Chain, North River Press, Great Barrington, MA.
[8] Horman, M., and Thomas, H. (2005). "Role of Inventory Buffers in Construction Labor Performance." J. Constr. Eng. Manage., 131(7), 834-943.
[9] Josephson, P., Larsson, B., and Li, H. (2002). "Illustrative Benchmarking Rework and Rework Costs in Swedish Construction Industry." J. Manage. Eng., 18(2), 76-83.
[10] Kolltveit, B. J., Karlsen, J. T., and GrØnhaug, K. (2004), "Exploiting Opportunities in Uncertainty During the Early Project Phase." J. Manage. Eng., 20(4), 134-140.
[11] Love, P., and Josephson, P. (2004). "Role of Error-Recovery Process in Projects." J. Manage. Eng., 20(2), 70-79.
[12] Park, M. (2004). "Model-based dynamic resource management for construction projects." J. Autcon.., 11.
[13] Park, M., and Pena-Mora, F. (2004). "Reliability Buffering for Construction Projects." J. Constr. Eng. Manage., 130(5), 626-637.
[14] Project Management Institute (PMI) (2004). PMBOK 3rd, Newtown Square, Pa