PLANNING AND MONITORING THE TACT OF WORK FLOW

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Abstract: To ensure a continuous and smooth work flow, this research proposes (1) Tact Scheduling Method as an alternative to traditional ones and (2) Work Flow Monitoring System (WFMS). Tact scheduling is intended to balance the unit activities of relevant work trades in terms of the duration and the labor input required for performing each activity. Subcontractors as well as the main contractor participate in the planning stage and adjust the same duration and the labor input for every unit activity by zoning the workspace. Prior to developing the WFMS, a few factors that are considered to possibly affect the variation of the work flow are defined and indicators to measure these factors are devised.

Keywords: Tact, Work Flow, Scheduling, Planning, Monitoring.

1. INTRODUCTION

As the buildings are become larger in size and taller, the aspect of time consumed for constructing buildings are now the most important factor to be considered in the planning stages. Among the various kinds of works involved in a building construction project, the finishing works need to be managed more carefully, since these works are very complex and at times are in conflict with themselves. One research by KICEM [1] reported that the duration for finishing works in Korea is much longer than those of other countries and that there is a need to develop a more effective management system for finishing. This is summarized in Table 1.

In order to reduce the time consumed for the finishing works in building construction, it is necessary to understand the characteristics of the finishing works such as the tact or rhythm of such works flow. This is also related to management of the cycle time of the finishing works. The impact of work flow variations and the importance of managing the work flow are well described in the Parade Game [2]. An efficiently and systematically predefined work space and crews for each works in that space enable the works processed in a given duration to be conducted in a controlled manner. This consequently minimizes the impact of flow variation.

The objectives of this research are two-fold: one is to explain the concept of tact schedule management method through a sample case study. This is not a new method in that it is a re-emerging concept as a schedule management tool due to the growing importance of work flows. This method is

Table 1. Comparison of building construction duration

Project Name		Floors		Total Duration (Month)	Earth Work Duration (Month)	Structural Work Duration (Month)	Finishing Work Duration (Month)
		Under Ground	Above Ground				
USA	Allied Bank	B4	71	30	9	15	6
	Hines	B2	53	23	6	12	5
	US Steel	B3	64	30	12	13	5
Japan	Landmark Tower	B4	70	37	11	20	6
	World Trade Center	B3	40	32	13	13	6
	Kobe Trade Center	B2	26	24	7	9	8
Korea	Big Way Tower	B7	21	29	7	12	11
	Bumcheon Bldg.	B5	25	29	7	13	19
	Dongyang Bldg.	B7	21	29	7	10	12

* Finishing work duration is measured after completion of structural works.

particularly discussed in connection with the management of repetitive construction works. The other objective is to present a concept for work flow monitoring system. This system is devised to monitor the work flows scheduled by using the tact schedule management method. Some variables, mainly related to labor factors, are suggested as indicators of work flow monitoring. The main focus of this paper is on the finishing works of building construction, since this kind of works is very repetitive and so, the tact of work flow shall be said to be more important compared to other works.

2. CURRENT SCHEDULE MANAGEMENT PRACTICES

The finishing works of multi-story building or high-rise building construction works are repetitive. These works are composed of activities that are of relatively smaller in work size but more in number than other works such as structural or earth works, and thus are normally executed by various subcontractors. Therefore, the managing approach should be different from that of structural or earth works. The main points in managing these works can be summarized as (1) the continuity of work flow and (2) the stability of resources in accordance with the work flow. In this regard, the current schedule management approach shall be said to have certain limitations as descried below: (1) Due to the insufficient consideration on productivity of each trade, the work flows among various trades are not being managed effectively. (2) An investigation on case projects has shown that there are many of idling time at the finishing work stages, which take up almost 45% of the finishing works duration. Most importantly, this idle time is due to the poor work flow as well as the instability of resources. (3) Discontinuous flows of repetitive works are also one of the reasons for the loss in productivity, since it reduces the possibility of increasing productivity through the learning effect. (4) Discontinuous work flow causes the problem of miscommunication among trade contractors, which resulted from poor communication network. This, in turn, negatively affects the work of the main contractor [3].
In addition to the problems mentioned above, the limitations of the critical-path method (CPM) in being applied to repetitive works are well described in the previous researches and can be summarized as follows: (1) It is not practical to consider the flow of works first and then attempt to control the variation of work flow by CPM. (2) CPM is more appropriate for long-term planning rather than for detailed task level planning. (3) Constraints of each activity are hardly reflected on CPM networks [2][4].
Another widely used schedule management tool is the line-of-balance (LOB) method. This is relatively efficient for repetitive works such as the construction of high-rise building, but it also has some limitations such as: (1) it is difficult to change the pace of activity or productivity from its initial setting and (2) it lacks the consideration of individual activities and their flows.
In order to overcome these problems, more attention should be paid on work flow and stability of resources during the development of construction schedules. In this regard, one of the effective scheduling techniques is the tact system or the so-called tact schedule management method.

3. TACT SCHEDULE MANAGEMENT

3.1 What is tact schedule management?

Major Japanese construction companies like Taisei have already adopted the tact system or tact schedule management method in the early 90s [5]. At that time, however, there was a lack of understanding in the concept of work flow or the stability of resources. In 2001, a major Korean construction company, Samsung Engineering & Construction, combined the tact system with the principles of lean construction [6]. In order to understand tact schedule management system, there are a few key concepts that need to be known first, as shown in Fig 1[7].

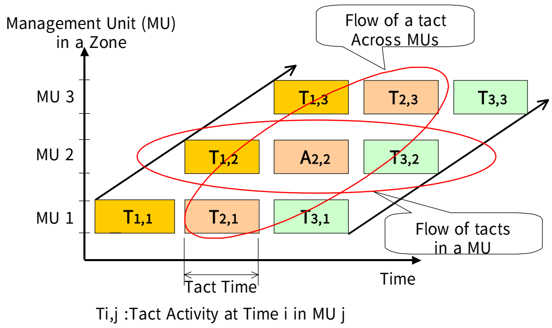

Fig 1. Key Concepts of Tact Schedule Mgmt.

1) Management Unit (MU)
This is the management unit based on workspace. In a multi-story building construction, a floor or a divided workspace in a floor shall be one unit. Each management unit will have the same work pattern. In addition to management unit, there are zones as well. A zone is a set of management units. For example of an apartment construction, a floor can be divided into two zones; public zone including elevator hall and private zone including residential units.
2) Tact Activity
This is one unit of activity or an element of network of works in a management unit. Each tact activity is executed sequentially in a management unit. A building construction can be described as a network (or flow) of management unit and each management unit can be described as a network of tact activity.
3) Tact Time
This is the duration of a tact activity and every tact activities. In tact schedule management, tact time

should be constant so that the entire tact can flow continuously. In other words, tact activities are executed in a synchronized manner at one time point. For tact time to be constant, the resources for tact activities should be well organized and stabilized.

3.2 Tact scheduling process

The general process for tact scheduling is described in Fig 2. Here, the main-contractor as well as sub-contractors is involved. In addition to this, monitoring proper indicators that show the performance of tact schedule management is important. This is an example of continuous improvement of schedule management.

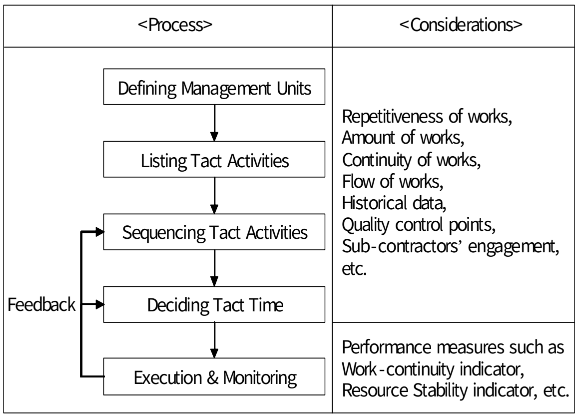

Fig 2. Process of tact scheduling

3.3 Tact schedule of a case project

The case project includes three blocks of building. In each block, underground parking garage and commercial facilities are positioned from LG4 to L2 or L1. Areas from L2 or L3 of each block are composed of total 142 units of apartments. The project team's efforts on tact scheduling in accordance with the process proposed above can be described as follows: (1) Work zones are divided into elevator hall zone, residential unit zone, and bath room zone in the residential units. Management units are defined by each zone on every floors of a building block. For example, residential unit zone on 12^{th} floor of block 102 becomes an independent management unit. (2) Tact activities are categorized into 26 tact activities for residential unit zone, 15 for bath room zone, and 10 for elevator hall zone are listed. (3) The listed tact activities are sequenced according to the predecessor-successor logics and tact time is set as 4 days considering the productivity and work amount of each tact activities. (4) A set of performance indicators are developed by the research team. These indicators are to monitor the effectiveness of tact schedule management and include Worker Loyalty (WL), Labor Resource Stability (LRS), and Work Flow (WF). These indicators form the basis for the development of work flow monitoring system, which will be further described in the following chapter.

Fig 3 is a part of the graphical presentation of the tact schedule developed for residential unit zone of block 102 of the case project. The finishing works duration of the case project was scheduled for 8 months. This is still longer than that of other countries, but quite shorter than other projects in the Korean building construction market.

4. WORK FLOW MONITORING SYSTEM (WFMS)

4.1 Key indicators for work flow

1) Basic assumptions

In order to achieve a performance goal, management must focus on controllable factors that affect the result among other issues. From this point of view, labor-related controllable factors are significant in achieving a continuous work flow in the repetitive construction work presented in Fig 3, since this type of work is considerably labor dependent. Therefore, a relationship among labor factors and work flow should be identified empirically so the managers can control the factors effectively.

A stable supply of quality labor is a common issue in construction projects. Quality labor means stability in providing skilled labor that possesses a certain level of skill. When the skill supplied for a trade is maintained at an acceptable level, the frequency of worker changes or stability of labor resource becomes a concern. That is, the instability of labor resources leads to deviations from normal workflow, and thus, the following hypothesis can be made.

H1: Labor Resource Stability will affect Work flow

One of the most fundamental causes of variations in achieving a target schedule is human factors, e.g., workers absenteeism or worker loyalty. Poor worker loyalty increases the possibility of schedule overruns, deviations from the normal work flow, and instability of labor resource. That is, worker loyalty is somehow related to workflow and labor resource stability. Therefore, the following hypotheses can be made.

H2: Worker Loyalty will affect Work flow

H3: Worker Loyalty will affect Labor Resource Stability

2) Measures for the key indicators

Work flow (WF)

From the standpoint of the contractor, the continuous work flow is an important success factor in terms of achieving project management goal. According to the planned schedule of the case project, waiting time should be constant or zero until moving to the next tack activity. However, in reality, irregular waiting time can occur. The measure of work flow in this research is the waiting time ratio (WTR). WTR is the ratio of 'the waiting time between any two consecutive activities' to 'the available working time' for a given period, and is calculated using Eq. (1). In

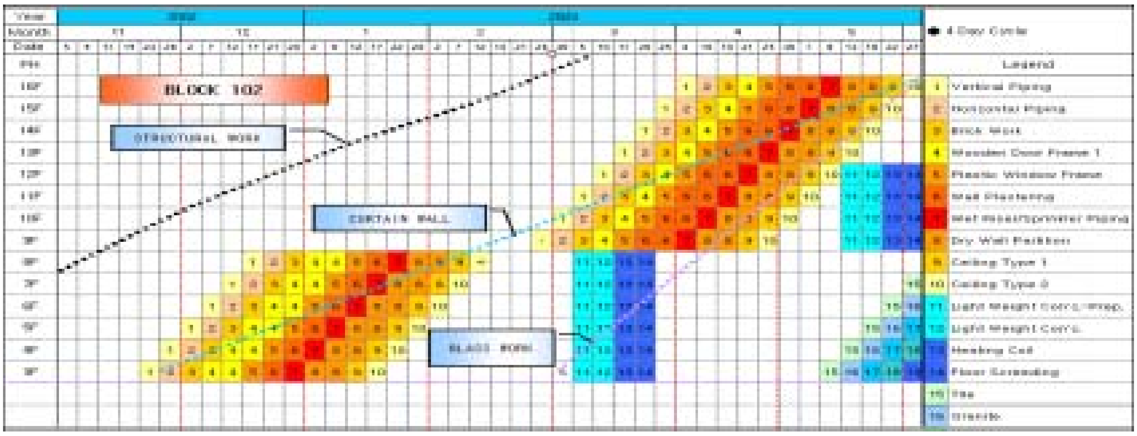

Fig 3. Parts of the tact schedule of the case project

the case study, WTR was measured at the sub-contractor level.

WTR = (Waiting time for a given period) / (Available working time for a given period) (1)

Labor resource stability (LRS)

When the planned schedule is developed, it is assumed that labor resource will be provided stably in terms of quality and quantity. However, during the construction process the number of workers on a trade varies from day to day and even the individual workers change. The measure of labor resource stability in this research is the worker change ratio (WCR). WCR is the ratio of 'the number of workers changed from the previous day' to 'the number of workers on the day', and is calculated using Eq. (2). In the case study, WCR was measured at the sub-contractor level.

WCR = (Nos. of workers changed from the previous day) / (Nos. of workers on a certain day) (2)

Worker loyalty (WL)

When the planned schedule is developed, worker loyalty is assumed to be quite consistent. However, absenteeism often occurs, and this has an effect on the overall project. The measure of worker loyalty in this research is the worker attendance ratio (WAR). WAR is the ratio of 'actual working days for a given period' to 'available working days for a given period', and is calculated using (3). In the case study, WAR was measured at the individual worker level and averaged at the sub-contractor level.

WAR = (Actual working days for a given period) / (Available working days for a given period) (3)

3) Verification of the key indicators

The verification of the key indicators suggested in this research is two fold: one is to confirm the content validity of the indicators and the other is to verify the relationship among the indicators in an empirical way.

Content validity

The purpose of content validity is to check if a measure or an indicator reflects the specific intended domain of the content. In other words, it is necessary to confirm that WAR, WCR, and WTR actually represent worker loyalty, labor resource stability, and workflow, respectively. The content validity was confirmed through 3~6 times of interviews with experts including four professors from universities, six managers from a construction company, and seven researchers from graduate schools.

Relationship among the indicators

To confirm the relationship among the indicators, raw data were collected from seven sub-contract works, on a daily basis over a four-month period from the case project. The indicators were computed on a monthly basis at the sub-contractor level, due to the program of the company job reporting system. A statistical analysis was also done at the month level. The correlation matrix of the indicators, as shown in Table 2, confirms that there are statistically significant correlations among the indicators.

Table 2. Correlation Matrix of Variables

	WL (WAR)	LRS (WCR)	WF (WTR)
WL (WAR)	1.000	–	–
LRS (WCR)	-0.744**	1.000	–
WF (WTR)	-0.562**	0.606**	1.000

** Correlation is significant at 0.01 level (2-tailed).

4.2 Conceptual model of WFMS

In order to control the tact schedule, a conceptual model of work flow monitoring system is presented in Fig 4. This model is based on the indicators and assumptions explained above. When the WTR is greater than one, it can be said that the work flow is out of control and thus further examination is required to find out the possible reasons in terms of the LRS and the WL. The WTR which is less than or equal to one implies that the work flow is controlled as scheduled. When the WCR is greater than zero, it can be said that the current labor resource is unstable and thus a proper action should be taken to control the labor stability. The WCR which is equal to zero implies that the current labor resource is supplied in a stable manner. When the WAR is less than one, it can be said that the worker's attendance is facing problems and thus a proper action should be taken to improve the labor loyalty. The WAR which is equal to one implies that the current labor loyalty is at the acceptable level.

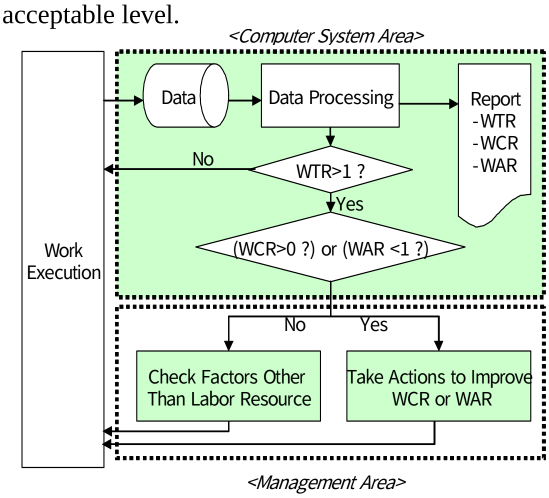

Fig 4. Conceptual model of WFMS

4.3 Implementation of WFMS; S-SMART

A computer system named S-SMART (Samsung Site Monitoring, Assessment and Reporting for Tact management) was developed for work flow monitoring in the case project. This system has two main functions: one is to monitor the work flow as explained above, and the other is to monitor the progress of works planned by the tact scheduling method as shown in chapter 3. Fig 5 below shows the development framework of S-SMART. As an illustrated example, the major functions of S-SMART are shown in the following paragraphs.

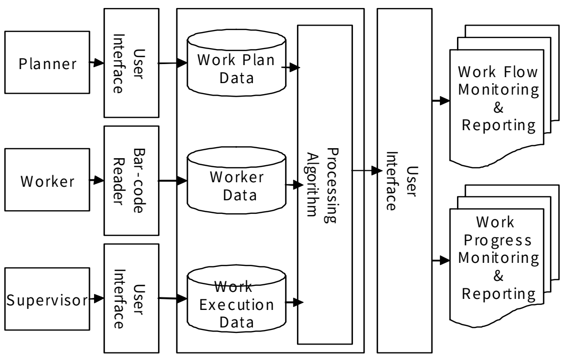

Fig 5: Development framework of S-SMART

Establishing the tact schedule by planners

After the basic planning of tact schedule, the schedule information is input into the system. The key information to be input are MU, tact name, tact time, sub-contractor, input labor quantity, etc. and these are coded and linked to each other. Fig 6 shows the tact schedule input task.

Reporting daily job by sub-contractors

The system provides daily job reporting function, which is previously done by manual (Fig 7). The information about the attended workers on a day is automatically migrated from the barcode reader (illustrated in Fig 5) to S-SMART. The supervisors of sub-contractors' then record the MU (the detailed location of work) and tact activity of the attended workers using preset menu in S-SMART.

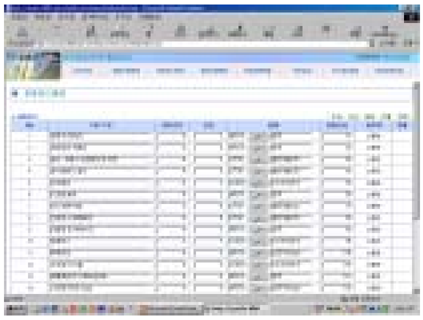

Fig 6. Establishing tact schedule

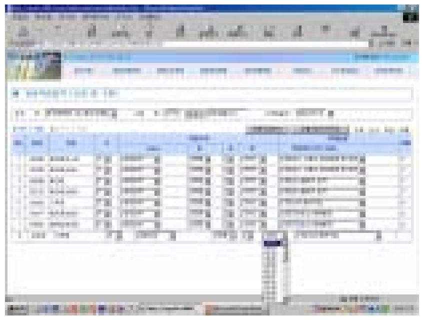

Fig 7. Reporting daily job by sub-contractors

Reporting the activity completion

The completed tact activity in a MU can be easily reported by checking the menu in S-SMART (Fig 8). The X-axis represents MUs and the Y-axis represents tact activities. When reported as completed activity by sub-contractors, the activity will be confirmed or rejected by main-contractor. The rejected activities will be marked in different color.

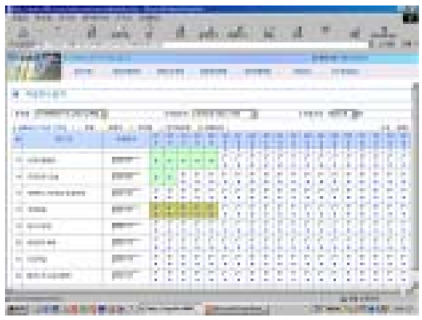

Fig 8. Reporting the activity completion

Monitoring the work progress

As shown in Fig 9, the work progresses can be clearly displayed for easy monitoring. The X-axis represents MUs and the Y-axis represents tact activities of a selected building block. At one glance, the progress can be captured. The number in the cells represents various information, e.g., input labor, finish date, start date, etc. The different color of the cells indicates that some of them are completed at first time and some others are completed by rework process. With this function, the overall status of work progress can be easily understood.

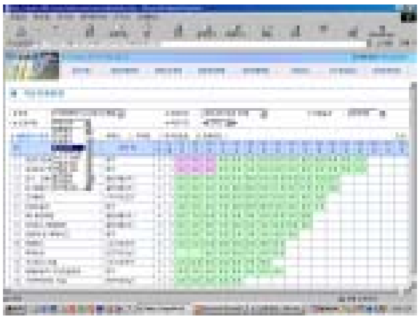

Fig 9. Monitoring the work progress

Monitoring the work flow with indicators

The work flow indicators, which are explained in section 4.1 are easily monitored by using S-SMART. The indicators can be analyzed against sub-contractors or MUs. This analysis is, as explained in Fig 4, to control the work flow. Fig 10 is showing the worker loyalty of the workers of a sub-contractor.

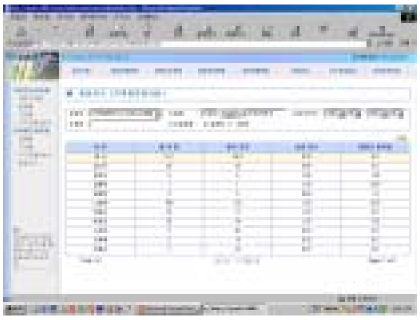

Fig 10. Monitoring the work flow with the indicators

5. CONCLUSION

Work flow is an important concept in lean construction, and its impacts on the effectiveness of construction process are well known. This paper viewed the tact or the rhythm of work flow as an important factor for managing continuous and repetitive works and proposed the tact scheduling method, the work flow indicators, and work flow monitoring system.

Firstly, a tact scheduling method —a planning method focused on the continuous work flow— is introduced. This method is believed to help reduce the duration consumed for conducting repetitive works by reducing the possibility of deviations from the planned work flow. By applying this method, the duration of finishing works of the case project was scheduled for 8 month, which is much shorter than previous Korean practices (see Table 1). This schedule was challenging but kept after all, and therefore, it can be concluded that the tact scheduling method is effective to manage the work flow of repetitive works and eventually to shorten the duration of repetitive works like finishing works of a building construction.

Secondly, a few indicators that measure the factors affecting the continuous work flow are suggested and validated. The logical concept of the indicators was validated through the intensive reviews by experts and the relationship among the indicators is statistically verified. Therefore, it can be concluded that the indicators proposed in this research are useful in monitoring the work flow of repetitive works scheduled by tact scheduling method.

Finally, this research presented the work flow monitoring system named S-SMART. This system is developed to support the overall process of tact schedule management and includes the followings as the major functions: establishing tact schedule, reporting daily job by sub-contractors, reporting the activity completion by sub-contractors, monitoring the work progress, and monitoring the work flow with the indicators. From the implementation of this system on the case project, it was found that the sub-contractors' involvement in the system use is quite challenging, however, the functions and performance of the system are satisfactory for supporting the process of the tact schedule management.

Acknowledgments

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