Management Thinking in the Earned Value Method System and the Last Planner System

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Abstract: Management theory has been neglected in the construction industry, which has rather focused on best practices. This paper investigates the theories implicit in two prevalent project control systems: the earned value method (EVM) and the last planner system (LPS). The study introduces two fundamental and competing conceptualizations of management: managing by means (MBM) and managing by results (MBR). The EVM is found to be based on MBR. However, project control based on MBR is argued to be inappropriate for managing at the operational level where tasks are highly interdependent. The LPS is found to be based on the MBM view. The empirical evidence from literature and case study suggested that the MBM view is more appropriate to manage works when it is applied to the operation level where each task is highly interdependent.

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Introduction

Many different project control tools and measures are used in the industry. With the advent of automation and information technology, some tools are computerized so that immense amounts of information can be processed easily. Such improved technology encourages managers to try to control projects at more detailed levels than before. However, improved tools using the advanced technology have not improved project performance.

It has been argued that improvement in practice cannot be achieved without improved theory (Koskela and Vrijhoef 2000; Koskela and Howell 2002). A theory provides an explanation of observed behavior and contributes to understanding as well as predicting future behavior (Koskela and Howell 2002). A theory also provides the basis for the development of tools for analyzing, designing, and controlling. It is argued that construction has not had an explicit theory (Koskela 2000; Koskela and Howell 2002). In an effort to establish a theory of construction, Koskela (1999) proposed to understand construction as a type of production. Bertelsen (2003) applied the theory of complex adaptive systems to construction. These have addressed the question: What is a project? There have also been some studies done on the question: What is project management? Koskela and Howell (2002) used the thermostat and scientific model to explain the features of traditional project management and lean project management. The contribution of this paper is to use management thinking underlying the project control tools from the perspective of the theory of project management.

This paper endeavors to answer the following questions. (1) What management thinking (theory of management) underlies project control methods and tools? (2) Is the managing by means (MBM) more suitable to daily project production system where each task is highly interdependent? The scope of the paper is limited in this paper in investigating the earned value method (EVM) and the last planner system (LPS). A theoretical investigation is used to answer the first question based on the dichotomy between MBM and managing by results (MBR) suggested by Johnson and Broms (2000). The second question is sought by a theoretical investigation focusing on the assumptions of EVM and LPS, followed by a field case study on how LPS and EVM are effective in managing daily production system as well as empirical evidences from literatures.

System Level versus Operational Level

Schedule activities or work packages tend to be different from work tasks (i.e., assignments) assigned to the field (Kim and Ballard 2002; Choo 2003). Schedule activities in project scheduling are still aggregate to be assigned to production units using daily or weekly production planning (Kim and Ballard 2000). In production planning, a unit of task, or assignment, is a smaller chuck of work unit driven from schedule activity. Assignments are "a directive or order given to a worker or workers directly producing or contributing to the production of design or construction" (Ballard 2000). The level of dependence among work units increases as the level of details of the work units does.

In this paper the works at the system level refer to the work units of which the level of dependence between one another is relatively low. Work package such as foundation concrete work can be an example. The works at the operational level, on the other hand, refer to the work units of which the level of dependence is relatively high. The example of work units at the operational level is the assignments of daily production planning.

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MBR

MBR Thinking

Johnson and Broms (2000) proposed a distinction in management theory between MBR and MBM. Traditionally, organizations are driven by financial targets believing that corporate goals can be achieved by each part of the organization (e.g., department or employee) reaching individual financial targets. Under this belief, a manager's role is to motivate employees to reach or exceed financial targets. Such management thinking was named by Johnson and Broms (2000) "managing by results."

MBR thinking comes from quantitative thinking, which restricts one's perception to only one imposed dimension, whereas nature and organization consist of multiple dimensions (Johnson and Broms 2000). This quantitative thinking assumes that the observers and objects are separate from and independent of each other. Quantitative generalizations apply to mechanistic systems whose interactions can be defined entirely in quantitative terms. MBR thinking is appropriate to mechanical systems because it neglects the attributes of organizations that differ from mechanical systems. MBR thinking adopts the reductionistic assumption that optimizing parts of a whole optimizes the whole. Organizational systems have even more complex relationships among their subsystems and parts, thus rendering the MBR reductionist assumption entirely inappropriate.

EVM

EVM is a project control technique, which provides a quantitative measure of work performance (Fleming 1983). It involves crediting dollars or labor hours based on unit rates for the various types of work performed. The earned value technique is said to be superior to independent schedule and cost control for evaluating work progress in order to identify potential schedule slippage and areas of budget overruns. Work package and variance analysis are major components of EVM.

A work breakdown structure (WBS) divides a project into the elements of work to be accomplished. Integrated with an organization breakdown structure that provides the "responsibility" field, WBS defines cost accounts, which function as management control points. Management control points represent the most detailed breakdown for project control where resources are allocated, costs are collected, and performance is formally assessed (McConnell 1984).

Each cost account is a control point. It is the lowest level at which individual variance analysis can be made. Variance analysis can be made at any point in a WBS hierarchy. Cost/schedule control system criteria issued by U.S. Department of Defense define a cost account as "a management control point at which actual cost can be accumulated and compared to budgeted cost for work performed.

Metrics

In EVM, the relevant variances are cost variance (CV) and schedule variance (SV). Data collected for analysis can be divided into three categories: actual cost of work performed (ACWP), budgeted cost of work performed (BCWP), and budgeted cost of work scheduled (BCWS).

ACWP is the actual incurred cost, usually in terms of dollars or labor hours, of work performed in a specified period of time.

Table 1. Schedule and Cost Performance from CV and SV

Variance	(−)	0	(+)
CV	Cost overrun	On budget	Cost underrun
SV	Behind schedule	On schedule	Ahead of schedule

BCWP, or earned value, is the budgeted value, usually in terms of dollars or labor hours, of work actually performed in a specified period of time.

BCWS is the budgeted value, usually in terms of dollars or labor hours, of work scheduled to be performed in a specified period of time.

Since the objective of EVM is to achieve an integrated cost/schedule progress monitoring and control system, it requires the monitoring of CV and SV as mentioned.

CV is the difference between the budgeted and actual costs of the work performed

$$CV = BCWP - ACWP$$

or

$$CV(\%) = (BCWP - ACWP)/BCWP$$

SV is the difference between the budgeted costs of work actually performed and the budgeted cost of the work scheduled to be performed

$$SV = BCWP - BCWS$$

or

$$SV(\%) = (BCWP - BCWS)/BCWS$$

The performance interpretations that may be drawn from CV and SV values are summarized in Table 1.

Cost and schedule performance are the objects to measure in the EVM. They are goals of the processes which include operation, planning, system reliability, etc. Managers make management decisions such as resource allocation based on the SV and CV in the EVM.

Assumptions

To investigate management thinking behind a project control method requires examining the assumptions of the method. EVM assumes that a project can be broken into independent subprojects (packages), with contractual responsibilities and quantitative targets attached (McConnell 1984). Packages are assumed to be independent of each other; i.e., they each represent a contractual obligation between one party (owner, general contractor, etc.) and multiple other parties (subcontractors), with no connection between one contract and another. It is assumed that a project will be successful if each work package resulting from WBS is managed and finished within its schedule/cost target. The goal of managers using this method is to improve financial performance (i.e., increasing earned value) of each account.

Management Thinking

From the perspective of management thinking, the EVM reflects MBR thinking based on the following:

1. WBS and CV analysis assume that every task or package is independent.
2. The objects to measure are cost and progress, which are results of the processes. Processes may include operations, planning, and system reliability.

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3. Management decisions such as releasing assignments are based on performance results such as CV or SV.

In project control, monitoring cost and progress to see if they are on the right track is critical. EVM should be used at the system level where elements are relatively independent. However, EVM is not appropriate for the operational level where tasks are highly interdependent. Kim and Ballard (2000) investigated the impacts of releasing assignments based on cost and progress criteria on work flow reliability. According to Kim and Ballard (2000), if budget and cost on each cost account are the main decision criteria for selecting work assignments, work flow becomes unreliable, which results in longer durations and higher costs than necessary, and schedule and cost overruns relative to target.

MBM

MBM Thinking

In contrast to MBR, Johnson and Broms (2000) used the term managing by means (MBM). According to Johnson and Broms (2000), the difference between MBR and MBM practices reflects the differences between the principles that govern natural living systems and those that govern mechanistic systems.

The nonmechanical world such as business organization is not separated into independent parts. It is not important to maximize output and efficiency of each part but to nurture relationships between parts. To manage projects or other forms of organization entails more than quantitative summing up of the separate contributions of each part (Johnson and Broms 2000; Johnson 1992).

The underlying belief of MBM is that what decides an organization's long-term profitability is the way it organizes its work. It is only by looking away from desired results that they can be achieved. Trying to optimize each part of an organization separately results in one part cannibalizing another and lowers the performance achieved by the entire system. Managers should be striving first to adhere to disciplined practices such as attention to how work is done, coordinating between parts of a system, and enabling those who do the work. An excellent example of this philosophy of management is provided by Liker's account of Toyota's management principles in his *The Toyota Way* (Liker 2004).

LPS

The LPS is a production planning and control tool to improve work flow reliability (Ballard 2000). Many companies have adopted the method and reported the results of case studies, and many reports and academic papers have provided evidence that last planner improves work flow reliability, thereby reducing project duration and cost (Kim and Jang 2005; Johansen and Porter 2003; Fiallo and Revelo 2002; Ballard et al. 2007).

The "last planner" is the last in the decision chain of the organization because the output of his/her planning process is not a directive for a lower level planning process but results in production. As shown in Fig. 1, last planner only releases workable jobs to the field, as opposed to the traditional practice of pushing assignments onto construction crews and design squads in order to meet scheduled dates. In addition to looking ahead and prescreening upcoming tasks for constraints, assignments are also expected to meet specific quality requirements for definition, sequence, and size. In addition, since mistakes will still be made, the control system is structured to promote learning from plan failures, in an effort to avoid making the same mistakes twice.

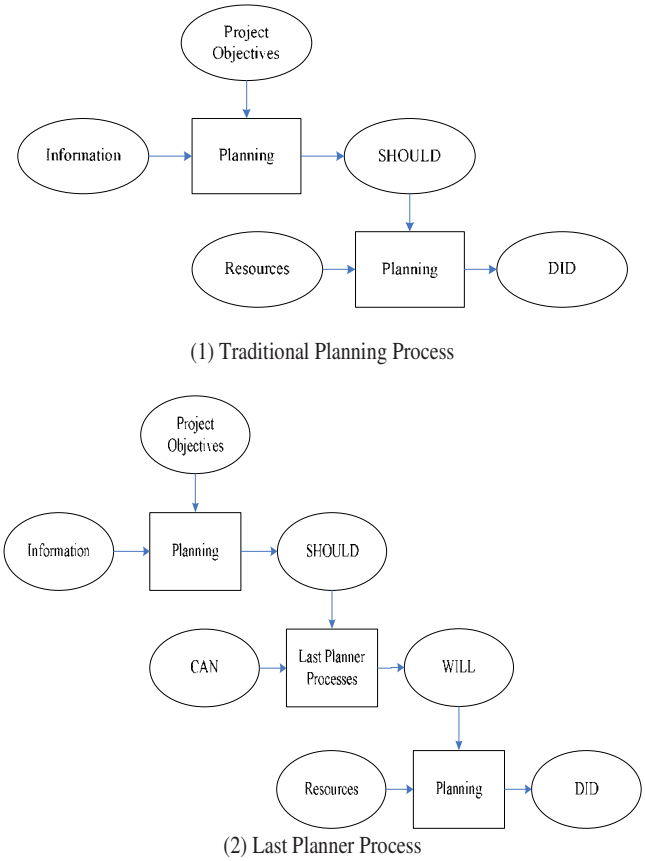

Fig. 1. Planning process (Ballard and Howell 1998)

Making quality assignments shields production units from work flow uncertainty, enabling those units to improve their own productivity and also to improve the productivity of the downstream production units that receive and build on their work and hence are dependent on reliable release of prerequisite work or shared resources in order to do their own planning (Ballard and Howell 1998).

Metrics

Percent plan complete (PPC) is a measure of workflow reliability (Ballard 2000) and is calculated by dividing the number of near-term tasks completed by the total number of tasks made for the plan period (Ballard 2000). The equation for PPC is as follows:

$$\text{PPC}\ (\%) = \frac{\text{number of completed tasks}}{\text{number of assigned tasks}} \times 100 \qquad (1)$$

Data required for PPC calculation are the number of assigned tasks and the number of completed tasks. They are easily acquired from project engineers or foremen without any additional time and effort. No additional monitoring such as of resource consumption is required for this measurement.

Assumption

The LPS assumes that scheduled tasks have uncertainties and constraints that inhibit them from being started or completed on time. Uncertainty and constraints in scheduled tasks may include timely availability of resources, shop drawings, or prerequisite

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work. These uncertainties and constraints are revealed and addressed in a lookahead planning process typically six weeks in duration. Only sound tasks are made eligible for inclusion in daily or weekly work plans. Lookahead planning, properly done, improves work flow reliability because tasks that have been screened for constraints and judged to be constraint-free are more likely to be completed when planned. Howell and Ballard (1996) argued further that cost and progress measurements are reliable only after planning reliability is achieved.

Management Thinking

While traditional project control (e.g., the EVM) focuses on managing activity by activity with MBR thinking, the focus of the last planner is placed on work flow reliability, i.e., the predictable handoff of work between specialists. The LPS reflects manage-by-means thinking.

1. Monitoring is focused on planning reliability, not on financial metrics.
2. The LPS assumes that scheduled tasks include uncertainty and constraints.
3. Management decisions are based on planning reliability, a prerequisite to cost and progress measures.

This view of production control belongs to MBM thinking. Many case study results suggest that such a view is effective in managing production.

Accounting Numbers versus Relationship

As seen in the EVM, MBR-based project control traditionally focuses on accounting numbers (i.e., budget and budgeted schedule), conceived with the purpose of minimizing negative variances from planned cost and schedule. On the contrary, the goal of MBM-based control is to improve the flow of work across production units, first making work flow reliable, then continuously improving the entire production system's performance.

Improving reliability leads to nurturing relationships with project participants. Building relationships comes from trusting each other. Trust comes from reliability, from being trustworthy, not from commitment or contract. In line with that, project control tools based on MBM thinking lead to nurturing relationships between project participants. Reducing cost and duration are by-products.

Which management thinking is appropriate for managing current projects? The question of what management thinking is appropriate for managing current projects requires investigating the characteristics of current construction projects. Construction projects are now often structurally complex and uncertain (Williams 1999). The number of participants involved in projects is increasing and projects are becoming increasingly pressed for time (Howell and Ballard 1996). A project may deal with an enormous number of handoffs of work (materials and information), which brings about high levels of uncertainty and interdependency. Such properties are found especially at the operational level. Reliability of work and information flow becomes more important than ever (Howell and Ballard 1996). Under such circumstances, research in the lean construction community has shown that work flow reliability must be achieved as a prerequisite in managing cost and schedule (Ballard and Howell 1998; Howell 1999).

Empirical Evidences from Literature

Many previous case studies are found to support the claim that the LPS is more appropriate in managing works at the operational level. Some studies specified the EVM being employed prior to implementing the LPS. Some did not specify a control tool prior to the LPS. However, since MBR is the philosophy of management underlying currently accepted practice, we could reasonably assume that most, if not all, projects on which the LPS has been implemented were previously managed using MBR tools, if not EVM specifically.

The writers led field trials (Ballard et al. 2007) of implementing the LPS as a means to manage works at the operational level on two different organizations: Abbott and Riley (Ballard et al. 2007) and Ilyang Construction (Ballard et al. 2007; Kim and Jang 2005).

Abbott is an owner company and Riley is a general contractor who applied the LPS in its pharmaceutical research and development center (process and equipment building system). The LPS was applied in their weekly production planning. PPC ranged from 54 to 94%. Partial results of the field trial were as follows:

1. The LPS forced to think about what should be completed each day.
2. The LPS led to better understanding of causes for not completing tasks.

Ilyang was the specialty contractor in earthwork and structural concrete work. They applied to ten heavy civil projects where the EVM was used prior to applying the LPS. The average PPC climbed from 50 to 80 s. The schedule performance index was improved by more than 10%.

Ballard et al. (2007) presented a statistical analysis to support their claim that the LPS improves their planning reliability (PPC) and productivity on a refinery facility project in Indiana. Kim and Jang (2005, 2006) presented case studies where the LPS improved the planning reliability as well as schedule/cost performance at the system level when applied to production planning at the operational level. It is noted that the projects used the EVM at the operational level prior to the LPS employed in their case study (Kim and Jang 2005).

Case Study

The writers investigated how MBM and MBR are effective in production planning and control at the operational level. The writers interviewed 12 project managers and 12 frontline managers on 22 projects where production planning at the operation level was implemented. Relevant production control documents such as weekly schedule were also analyzed.

Interview Questions

The case study focused on how the work is planned and controlled at the operational level. In specific, we asked what tool(s) is being employed to manage works at their daily and weekly planning. More than one tool can be employed. For example, the LPS and EVM can be used simultaneously. The researchers also investigated the way works are managed underlying the tools in that the approach in managing works can be different though the same tool is being employed. In that regard, we investigated how they evaluate their performances including a way of feedback. Detailed interview questions are presented in the Appendix.

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Table 2. Summary of Interview Results

	Yes	No
Use last planner system?	22	0
CPI improvement after the LPS was adopted?	8 (over 20% improvement); 10 (over 10% improvement); 3 (0–10% improvement); 1 (0–10% decrease)	
Use PPC as a measurement?	22	0
Measure reason for failure?	18	4
Do root-cause analysis?	9	13
Measure cost performance at the operational level?	7	15
Is shielding priority in assigning tasks?	14	8

Note: The number of respondents is 22.

Case Study Results

All interviewees answered that they used the LPS as a production management tool. However, only nine projects used root-cause analysis while other projects calculated PPC only as a feedback. Seven out of 22 projects used the EVM where cost information is assigned to daily tasks simultaneously to manage their works at the operational level (Table 2). Shielding which prevents assignment uncertainty from flowing into the crew was not an assignment priority in projects where the EVM was employed though they still adopt the LPS apparently. Costs or schedules are priority in assigning tasks to the crew in projects where the EVM was employed at the operational level with the LPS. Those projects were not implementing MBM-based control because they did not fully implement the LPS.

Project Performance

Eighteen projects gained more than 10% improvements in monthly cost performance index (CPI) actual costs/budget. This result is in line with the finding of other research results that show the relations between the planning reliability and the project performance (Jang and Kim 2007; Ballard et al. 2007)

Measuring Means versus Results

All projects used PPC as a measurement for planning reliability. Eighteen projects recorded reasons for failure (i.e., why the assigned task was not completed), and only nine projects out of 18 projects did root-cause analysis, a class of problem solving methods aimed at identifying the root causes of problems or events such as 5 Why (Liker 2004). Six projects out of nine projects that did root-cause analysis gained more than 20% improvements in CPI.

Seven projects assigned cost information to daily tasks and measured cost performance at the operational level. Superintendents of eight projects said that they consider earned value as a priority in assigning tasks compared to quality criteria (i.e., definition, soundness, sequence, size, and learning) (Ballard 2000). We found that the way the works at those projects are managed is governed by the MBR thinking in that the project used the EVM as a project control tool at the operational level even though the MRM tool (LPS) is still employed simultaneously. The result suggests that the tool itself does not necessarily lead to the way tool is devised.

Results from case studies suggest that MBM thinking and practice tend to improve cost performance. By creating the right conditions for performance, performance can be improved. In implementing the last planner, some managers were found to use it as a micro-MBR management tool by assigning and tracking costs on each weekly assignment. If cost information is incorporated into the weekly work plan before the culture of reliable promising is well established (Macomber and Howell 2003), it easily becomes the main decision criterion for releasing work assignments rather than the five quality criteria; thereby work flow can become unreliable. Unreliable work flow leads to longer durations and higher costs than estimated (Kim and Ballard 2000; Kim 2002; Kim and Jang 2005). Quality assignment criteria are likely to be sacrificed to earned value.

Conclusions

We investigated two research questions: (1) What management thinking (theory of management) underlies project control methods and tools? (2) Is the MBM more suitable to daily project production system where each task is highly interdependent?

This paper contributes to a theory of project management by introducing and developing two fundamental and competing conceptualizations of operations management: MBM thinking and MBR thinking. We explored the theoretical implications, especially management thinking, of two project control tools: the EVM and the LPS. It argues that the EVM comes from MBR thinking, but that project control based on MBR is not appropriate for managing works at the operational level. This paper presented the LPS as an example of methods reflecting the MBM view.

This paper used a field case study and empirical evidences from literatures to test the claim that MBM is more appropriate way to manage works at the operational level. The case study and empirical evidences from literatures suggested that the production planning based on MBM thinking showed better performance when it is applied to the operation level where each task is highly interdependent. The case study also suggested that the way the tool is used is as important as what tool is being employed.

Appendix: Interview Questions

1. Describe your project.
2. How do you plan and control your production (production control)?
3. What are the criteria in assigning and prioritizing tasks to crew?
4. How do you evaluate and measure your production plan?
5. If you use PPC (the number of tasks completed/the number

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of tasks assigned × 100%), do you identify reasons for failure on noncompleted tasks?
6. How did the use of the LPS change the performance?
7. Do you measure cost performance or earned value at the assignment level?
8. If you use an earned value or cost measures at the assignment level, does it impact your decision-making process in releasing tasks to your crew?
9. Are there any barriers limiting the use of the LPS?

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