EVALUATING SITE PERFORMANCE THROUGH THE TFV-THEORY

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ABSTRACT

The objective of this paper is to evaluate how our understanding and findings change when moving from the traditional conceptual model of productivity to analyzing performance through the TFV-theory.

This paper first endeavours to compare the original prescription of the traditional conceptual model of productivity and performance with TFV-theory through literature study. This comparison is carried out in the context of construction management. To investigate the differences in practice, two case study sets of data were analyzed. Performance data on each of the 27 tasks was evaluated from transformation, flow and value view. This exercise illustrates how a performance evaluation through the TFV-theory focuses, besides the transformations (T), on the delays and production rate differences (F) as well as on quality or safety performance (V). In so doing, it addresses the possible causes of poor performance, and also the related solutions. These causes and solutions remain invisible in productivity evaluations.

KEY WORDS: TFV-theory, transformation, flow, value, production, site performance, lean construction.

INTRODUCTION

The theoretical basis of the conventional doctrine of project management holds production as transformation of inputs (money, physical units) to outputs (money, man-hours). Construction process is seen as a basically ordered system where order should be improved as much as possible and where unforeseen events unfortunately happen from time to time. Also performance is often seen only as conventional productivity. However, this commonly accepted theory of project has also been criticized regarding weaknesses in its common practices and a broader management perspectives have been suggested (Koskela 1993, Ballard & Howell 1994; Koskela, 2000, Koskela and Howell 2002).

In the TFV-theory, too, production is viewed as transformation of inputs and outputs, but also as flow where there in addition to transformation, are waiting, inspection and moving stages. The third concept views production even as a means for the fulfilment of customer needs (Koskela, 2000). The question is – what are the differences when evaluating production performance through the TFV-model compared to evaluating productivity, backed by the traditional transformation model?

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METHODOLOGY

This paper compares the prescription of the traditional conceptual transformation model of productivity and TFV-theory through a literature study. This comparison is carried out in the context of construction management concentrating on the differences between measuring productivity and performance.

To investigate the differences in practice, the results of two case studies are analyzed. Case set A includes performance data that was followed-up in a case study on each of the ten sites on one task on each of six different companies. Data consisted of planned cost (target estimate value), actual cost, planned duration (phase schedule), actual duration, starting and ending dates, time the foremen spent on supervising, the time the workers spent on the investigated task. On each site one construction task followed and the hours spent on it were collected from all the workers as well as the foremen. On five sites, the task followed-up was the installation of gypsum board partition walls and on four sites waterproofing and tiling. On one site the task was fixture installation.

Case set B includes data from 17 tasks. Data includes daily work achievement, work-hours and possible disturbances. The site foremen and researchers categorized the disturbances into eight groups according to their primary cause: design, directives (instructions, agreements, decisions), crew, equipment, work space, previous work, material and external conditions. The performance of the 17 case tasks was evaluated through these disturbances and production rates from transformation, flow and value view.

PRODUCTIVITY AND PERFORMANCE

PRODUCTIVITY

The meaning of the term productivity varies with its application to different areas of the industry, and it has been understood for a long time that a single industry measurement is insufficient (Measuring productivity, 1982).

Traditionally in industry there have been three common productivity measurements in use (Oglesby et al., 1989) – an economic model of total factor productivity (TFP), a project-specific model that defines productivity as total productivity (TP) and an activity-oriented model defining productivity as labour productivity. Labour productivity is the ratio between outputs expressed in specific physical units (for example volume of concrete) and inputs expressed as man-hours (Arditi, D. & Mochtar, K., 2000).

The traditional interpretation of productivity, focusing on labour or the efficient use of resources on site, cannot reflect the complex and diverse competitive conditions of modern business (Monga, 2000). It is widely realized that productivity is influenced very much by project and site management. In addition to site activities, construction productivity measurement includes the assessment of a range of functions and factors, including design, specification, standards and standardization, quality and economy regulation and inspection (Rau, 1988).

A considerable body of knowledge exists on labour inefficiencies. Site operations are subject to many disruptions related to workforce management practices, and these disruptions usually result in significant economic loss (Thomas, 2008). For example ineffective material management leads to the inefficient use of labour. A number of reports such as Thomas (1999), Horner & Talhouni (1993), Zhao & Chua (2003) and Thomas (2008) contain extensive bibliographies of published literature on the causes and effects on this subject. These reports state that the main causes of labour inefficiency relate to ineffective utilization of resources (labour, materials, equipment and information), unfavourable working conditions (congestion and out-of-sequence work) and adverse weather.

PERFORMANCE

Performance is not the same thing to all organizations, and it even means different things to different stakeholders of the same organization or project (Williams 1999). Sanvido et al. (1992) state that few objectives are common to all participants. Still they should be. Everyone expects financial profit and wants projects to be completed on schedule. Also the absence of any legal claims or proceedings is an outcome desired by all. Each stakeholder wants her task to go smoothly, without interruptions, in time and budget, according to the quality requirements, safely and in good co-operation with other stakeholders. Could this be what good site performance is about? Could it be effectiveness, efficiency and participant satisfaction? Could it be that in this case flow and value matter in addition to transformation?

DISCUSSION

Although productivity and performance are time honoured concepts in connection to site operations, we cannot be content with them. Although productivity measurements have been done in several decades, they have hardly helped improvement of productivity in construction. On the other hand, there is hardly consensus on what constitutes performance.

It can also be argued that terms such as “productivity”, and “performance” are not independent, self-contained concepts – rather they are embedded in different conceptualizations of production, which provide their meaning. Thus, it is worthwhile to examine such concepts of production, for trying to clarify these terms.

TRANSFORMATION, FLOW AND VALUE

The Transformation-Flow-Value (TFV) model (Koskela 2000) offers inspiration for the understanding of different aspects of the construction project. In the first concept, production is viewed as a transformation (T) of inputs to outputs (eq. traditional productivity). The second concept views production as a flow (F), where, in addition to transformation, there are waiting, inspection and moving stages. The third concept views production as means of fulfillment of customer needs adding value (V). According to Koskela (2000) these three concepts of production need to be integrated and balanced.

Depending on what basic concept of production one selects, one ends up with a very different prescription of production. For example the transformation model suggests using buffers between workstations as the flow model suggests eliminating buffers. Also regarding measuring performance, a very different prescription follows from each concept. One of the main theoretical arguments in lean construction has been that the traditional production control and measurement methods focus on transformation of inputs and outputs ignoring flows and value generation (Koskela, 2000).

TRANSFORMATION AND RELATED MEASURES

Actually, the concept of productivity directly focuses on transformation. (Koskela et al., 2007). Some resources are used to get certain results – input and output. Both input and output are usually understood as things or matter. Transformation itself is like a black box except that we can decompose it into further transformations (tasks). Thus the transformation model overcomes the difficulty of representing change by jumping over it (Koskela et al., 2007). All in all, comparison between input and output, productivity, is the primary measure for the transformation concept.

The common assessment of the success of construction projects and tasks - good performance - is that they are delivered on time, to budget, to technical specification and meet client satisfaction (Baker et al., 1983; Slevin and Pinto, 1986; Morris and Hough, 1987; Turner, 1993). Thus, performance indicators tend to focus on the result of the project not on processes (Moon et al., 2007). In this sense, also these measures are transformation oriented.

FLOW AND RELATED MEASURES

Since the foundation of the IGLC community researchers have seen the construction process as a flow of work (Koskela 1993; Ballard 1994), and new management principles for construction (Bertelsen and Koskela, 2002) have been developed. The virtue of flow production lies in the fact that it brings all inconsistencies into the light of day and so provides the opportunity for correcting them (Woollard & Emiliani, 2009).

In lean terminology, those inconsistencies are called waste. This term is often used synonymously with the term non-value adding costs (Buzby, et al., 2002). Womack and Jones (1996) define waste as "any activity, which absorbs resources but creates no value". The seminal authors on Toyota Production System (TPS) have identified seven major types of non-value adding activities: overproduction, waiting, transportation or conveyance, over processing or incorrect processing, excess inventory, unnecessary movement and defects (Ohno, 1988). Performance measurement from a flow perspective focuses primarily on such wastes.

Subsequent authors have suggested additions to this list (Emiliani, 1998; Laraia, 1999; Koskela, 2004; Liker, 2004; Macomber & Howell, 2004). Koskela (2004) states that the eighth waste is "making-do". This refers to a situation where a task is started without all its standard inputs or the execution of a task is continued although the availability of at least one standard input has ceased. The term input refers here not only to materials but also to all other inputs such as machinery, tools, personnel, external conditions, designs, instructions etc. Making-do as a waste has a great impact on the performance and labour productivity of activities. When acknowledged, detailed analysis of the activities and measurements on site reveal also this waste among others.

VALUE AND RELATED MEASURES

Bertelsen and Koskela (2002) see construction as a value generator for the client. According to them value is delivered as a series of processes forming a workflow drawing on transformations delivered by the trade contractors under a contractual arrangement with the client. In the framework of this concept, performance measurement is directed to total value provided or value provided by individual tasks. The quality movement has developed many ways of measuring value (or value loss, like defects, rework etc.)

Patton (2008) has introduced a new type of value loss: task diminishment. The actual value of the delivered project will usually be less than the expected value of purchased project. Poor task execution that is never discovered or restored, can lead to value degradation, or value diminishment during the construction process. The accumulation or stacking effect of these diminished tasks can represent a significant loss to overall purchased project value. Tasks are diminished in all trades, independently. Task diminishment exists when a specified design or construction task is not executed to its specified conditions. So bad design executed properly can have no task diminishment associated with it. (Patton, 2008)

FINDINGS

Here, we evaluate how sites succeed in planning and controlling production efficiently, on schedule and budget, safely, according to quality requirements, improving performance by reducing delays, getting the work done in the best constructability sequence, matching manpower to available work, coordinating multiple interdependent activities, etc.

According to the traditional conceptual model, the productivity of those tasks under budget (7/10) would be considered satisfactory. Table 1 shows also how much supervision was needed for the task execution according to the site managers and foremen. The bigger the “supervision” percentage the more time spent during the task execution.

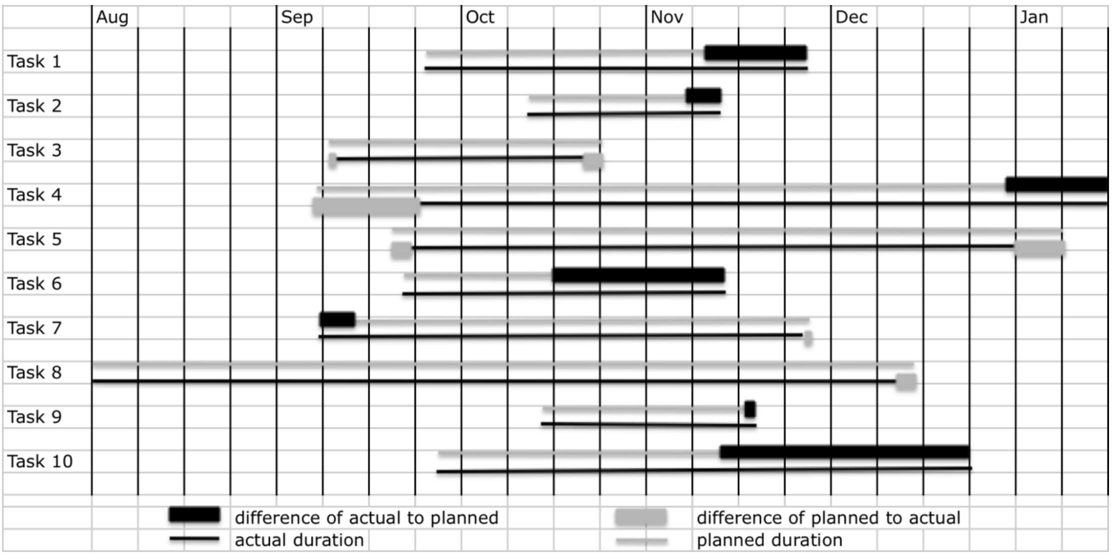

Figure 1: Task duration and timing in ten case tasks (Case set A) on ten sites. Planned duration is gray and actual duration is black. The difference in the planned is shown in thick black and in the actual duration in thick gray.

As Figure 1 shows not one of the tasks in our first set of case sites went according to the plan. Some started earlier, some later, some ended before planned and some after the set deadline. Table 1 shows how actual costs in these ten tasks are still below the budget in 70% of the cases, although the scheduled duration can be kept only in 30% of cases. Actual and planned costs and durations do not have significant correlation. Budget can be kept although our task duration is double of the planned. How can that be possible? Could there be some leeway, loss or waste?

"Re-doing" percentage (Table 1) shows the share of apartments, in which at least some rework had to be done. "Without remarks" demonstrates how much of the work could be done without the foreman having to intervene in task execution. The bigger the number the less remarks. "Safety gear" usage is also shown as percentage. "View" tells the main managing perspective that the site manager or foreman stated when interviewed before the task execution started on the site.

Task number 8 was the only one gone both according to the plan, in time and on budget. Also safety issues were taken care of. Supervision and re-doing were at a normal level, but the amount of remarks was highest (without remarks 10%). On the other hand, task number 3 was the only case both over the budget and with exceeded duration, obviously due to low supervision level. Neither the quality (re-doing 38%) nor the safety level was in order. Still in this task, there were fewer remarks from the foremen than in task number 8, which went according to the plan. To manage production well and to create value and to take care of the flow needs in these examined cases seem to require constant supervisory effort and an active leadership from the foremen.

Table 1: Time, quality, safety and cost variables (Case set A) (numerical values presented as percentages)

Variable	1	2	3	4	5	6	7	8	9	10
Actual cost/planned cost	89	91	113	148	107	91	97	99	86	98
Actual duration/planned duration	129	116	118	99	94	200	107	98	104	180
Supervision hours/work-hours	9	9	4	8	6	3	20	7	7	2
Re-doing of work spaces	29	0	38	40	6	8	18	12	13	23
Without remarks	50	33	20	25	100	33	20	10	100	10
Safety gear in use	100	50	50	50	67	50	67	100	75	50
View (Time, Quality, Cost)	T	Q	T	T	T	C	Q	T	C	T

Table 2 shows the data from 17 tasks (Case set B), including daily achievement, work-hours and possible disturbances. The work rate differs on average 19%. In most cases (11/17), the actual work rate is faster than the planned. Still only in six cases, the actual duration was shorter than the planned. The main issue is variation in the work rate.

In all of the 17 tasks, there were disturbances (or waste) either in the beginning (for example, getting started late, or with production rate that is not planned ≈ "making-do"), in the middle (one or more of the pre-requisites is not in order, work rate not as planned) or in the end (not finishing as planned).

Table 2: Work rates in 17 tasks. Planned, actual, minimum and maximum and the differences of actual vs planned. (Case set B).

	Work rate (unit/day)				Work rate (unit/day)			
Case	Planned	Actual	Diff.	Diff. %	Min	Max	Diff.	Diff .%
1	29	31	1,5	5,3 %	23	39	15	67 %
2	29	41	12	43 %	33	48	15	47 %
3	26	39	12	47 %	29	58	29	100 %
4	29	41	12	43 %	29	46	17	60 %
5	31	20	-11	-34 %	4,3	75	71	1650 %
6	31	24	-6,5	-21 %	2,5	31	29	1140 %
7	31	25	-5,8	-19 %	10	31	21	210 %
8	31	27	-4,2	-14 %	19	39	20	108 %
9	20	51	31	155 %	13	69	55	414 %
10	0,9	0,9	0,0	0,0 %	0,7	1,8	1,1	158 %
11	57	61	3,9	6,8 %	8,7	170	161	1856 %
12	23	18	-5,9	-25 %	1,7	38	37	2140 %
13	34	61	27	78 %	48	68	20	42 %
14	67	160	93	139 %	28	450	422	1507 %
15	0,6	0,6	-0,1	-9,1 %	0,3	2,7	2,4	800 %
16	1,3	0,8	-0,5	-36 %	0,5	1,3	0,8	167 %
17	8,0	5,0	-3,0	-37 %	3,3	9,6	6,3	188 %
AVER.	26	36	9		15	69	54	

It seems that the ability to perform does not benefit the project or the work gang due to different disruptions. Figure 2 shows how pre-requisites affect the work rate.

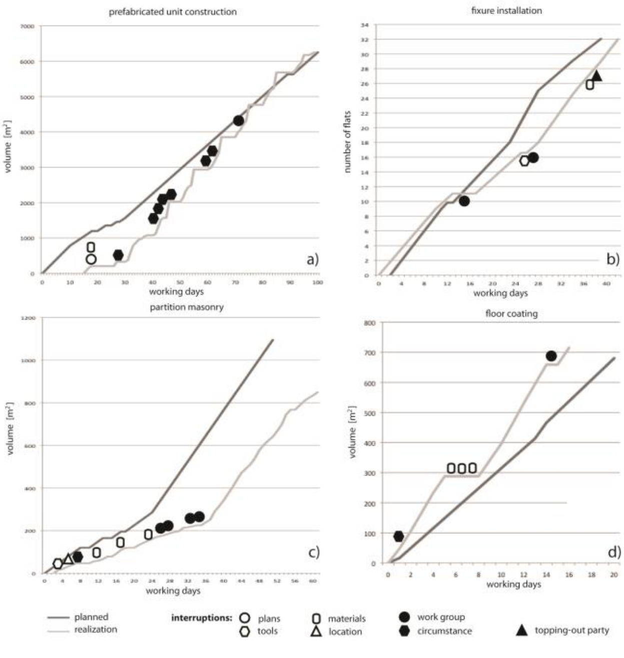

Figure 2: The planned and actual work rate in four cases of the set B. Disruptions and making-do effect is seen in the work rate. When pre-requisites are in order, the planned work rate is achieved. When pre-requisites are not in order, neither is the work rate as planned.

DISCUSSION

Production includes transforming the design and materials into products, the flow of information, design, materials etc. in such a manner that we gain value on every step of the way. To build productively requires us to manage our sites not only thinking of budget or schedule (Figure 1 and Table 1). Construction productivity measurement methods are limited because they do not take flow and adding value into account.

The budget (cases 6-10, set A) can be kept by buying “cheap” from a subcontractor. However, in only one of these five cases, the schedule could be kept. On the other hand, if the task duration is our “normative” production rate, only three out of the ten tasks are productive (Table 1). What makes the difference? The flow of production is not measured, the cost of tasks is. Waste and non-value adding activities are accepted and admitted into our production plans and schedules (Koskenvesa et al., 2010).

The construction process includes multiple phases, and hundreds of tasks. How can we ensure that best possible value is created when executing tasks? Value loss potentially impacts all of the tasks. Table 1 shows how much re-work is done (there was some re-work done in up to 40% of the flats) and still the budget could be kept in many cases. There is a lot of value loss and so the value generated could have been a whole lot better.

Table 2 and Figure 2 are examples of the effect that flow, taking care of the pre-requisites and proactive managing, has on production. Neither best value nor planned transformation can be achieved if the flow of materials, design, information, equipment, work group etc. is not taken care of. The work flows of these tasks show that production planning faces problems such as inherent uncertainty of task durations and associated opportunistic behaviour in establishing the true duration of tasks, and resourcing of tasks. On site, the managers and foremen have a strong tendency to start work even if not all resources required for the completion of the task are available. This “making-do” (Koskela, 2004) and “multi-tasking” tendency has the inevitable result of increasing the variability of task durations by introducing greater uncertainty, and extending average task durations.

CONCLUSIONS

Based on the TFV-theory, the Lean Project Delivery System (LPDS) proposes that it is the responsibility of management to ensure that tasks are executed as efficiently as possible in a collaborative context. Efficient task management will reduce variability in task execution, and because the distribution of durations is skewed towards the pessimistic end, it will also reduce the average of task execution times (Winch, 2010).

These ideas are not new. Already in 1919 Henry L. Gantt stated: “In as much as, according to our idea of management, it is the foreman’s function to remove the obstacles confronting the workmen, and to teach them how to do their work, an average of the performance of the workmen is a very fair measure of the efficiency of the foreman” (Gantt, 1919). But for realizing efficient task management, sites have to be measured and evaluated both regarding the transformation, flow and value angles.

All factors adding value to the construction process must be considered within performance assessment. Better performance will result from aligning internal and external factors. Performance studied through the TFV-theory shows the delays (Figure 1 and Figure 2), production rate differences (Table 2 and Figure 2) as well as quality or safety performance (Table 1). When we improve quality, costs decrease, there is less rework and we have fewer accidents, mistakes, delays and snags. We also have better use of equipment and materials. The site performance becomes better, and as a by-product, also the productivity.

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