BRIDGING THE GAPS – TOWARDS A COMPREHENSIVE UNDERSTANDING OF LEAN CONSTRUCTION

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ABSTRACT

Since the start of the work on the Lean Construction theory and methods in 1993, two major contributions have governed the process as seen from practice. One is Lauri Koskela's understanding of construction as a production, based on the Transformation-Flow-Value concept (the TFV-concept), the other is Glenn Ballard and Greg Howell's Last Planner method of production control.

These two contributions still stand as two isolated islands even though a number of ideas have been presented in order to bridge the gap between them, concerning for instance the understanding of project management, the value generation process and the cooperation during the project life cycle.

The paper highlights and discusses the primary understanding behind the two main lines of thinking and proposes minor modifications to the two major theories. Three more viewpoints on construction are then proposed as stepping-stones across the gap between the main islands. The use of these principles in project management is briefly touched upon with a reference to recent Danish experiences.

Finally, areas for further research are proposed.

KEY WORDS

Construction, production theory, Last Planner, complexity, project management

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INTRODUCTION

The work on Lean Construction has up till now to a great extent been focussed on two major areas in the understanding of the application and implementation of the new production principles in construction: Understanding construction as a production, and planning and managing the workflow within the construction process. Lauri Koskela has been the outstanding leader in the first area; Glenn Ballard seconded by Gregg Howell and others in the second.

This paper outlines the two major areas and discusses them briefly. In this, minor revisions are suggested. Even though references are made between these two contributions, they also stand as two islands not firmly interrelated. The paper thus proceeds by suggesting three more viewpoints to the construction process, supplementing Koskela's three basic ones and explaining to a greater extent the generality of the Last Planner methods. Based on this thoughts on a new view upon project management is proposed.

The paper is to a great extent based on the author's experiences from the ongoing Danish development of the construction industry in general and its productivity and value generation in particular. (Bertelsen and Nielsen 1999; Bertelsen et al. 2001)

These experiences are now put into a more scientific framework in a very unscientific way by an author that is not himself a scientist. *It is easier to act our way into a new way of thinking, than it is to think our way into a new way of acting.*[2]

LEAN CONSTRUCTION THEORIES

CONSTRUCTION AS A PRODUCTION

Lauri Koskela introduced his understanding of the construction process in the groundbreaking 1992-paper: Application of the New Production Philosophy to Construction (Koskela 1992). It has been elaborated upon in his later works and has for now found its final form in his dissertation: An Exploration Towards a Production Theory and its Application to Construction (Koskela 2000).

In this, Koskela explains that production since the end of the 18'hundreds has been seen from different viewpoints. First as a line of transformations each adding value to the product, since World War II as a flow taking the time aspect into consideration and a little later as a value generating effort.

Production as Transformation

This understanding means that production can be seen as a number of discrete steps, each independently adding to the value of the product. Optimizing each or any of the operations will move the process as a whole towards an optimized condition.

Construction is normally understood in this way even today, and procurements are made accordingly. Lowest price for each operation, order, contract or purchase is expected to lead inevitably to the lowest total cost for the project as a whole.

[2] Michael R. Lissack (1996): Chaos and Complexity – What does that have to do with management?

Production as Flow

Based on the example provided by Henry Ford, this concept was introduced by the Japanese car manufacturing industry and developed especially by Shigeo Shingo and Taiichi Ohno (Shingo 1988; Ohno 1978). The works of Womack et al (1990, 1996) introduced the concept to the Western industry in a popular form in 1990 by coining the term *Lean Production.*

From this point of view, production is seen as a series of activities, where some are adding value, others are not. The objective in optimizing the process is thus to reduce the non-value adding activities and to optimize the value adding ones.

As it can be found that there are more non-value adding activities than value adding, this moves the focus from the optimization of the value generation to the reduction of waste.

The construction industry has yet to understand this. The perspective of time is still defined as the time used for the transformations only, not as the sum of the time spent on transformation *and* on the non-value generating activities: inspection, transport, and movement.[3] And the construction has indeed quite a lot of such activities. Hammarlund and Rydén (1989) show that two thirds of Swedish plumbers' working time on the construction site is used on such non-value generating activities, a fact which is confirmed by Nielsen and Kristensen's (2001) studies of the erection of prefabricated concrete walls on a Danish construction site.

Experiments using just-in-time logistics in the construction industry have demonstrated substantial benefits, but the methods have been very hard to implement in general. The reason is that an efficient flow of materials to the construction site calls for a more reliable work planning than construction can normally provide. (Bertelsen and Nielsen 1997)

Production as Generation of Value

As production became more lean – and by that also more efficient – the market started calling for more interesting products. The mass produced product went out of fashion, and the individualized product came in. Production became perceived as a value generating activity, and the process had to become agile, if it wanted to survive.

The construction industry is a service provider. Its production is performed by a combination of trades, and it has always been oriented towards generating value. It is the nature of service and it is what the industry believes it provides. But the industry – not having a well-defined product – has no tradition of really looking into what the true value of its output is. The client's value parameters are not stated clearly at the outset of the project and their fulfillment is not monitored systematically through the project life cycle.

Discussion

The TFV-concept opens up a complete new view upon the construction industry, and it gives rise to new approaches to the management of the process, as discussed later.

However, Koskela's perception of the differences between transformation and flow differs somewhat from the Japanese understanding as expressed by Shingo (1988). Koskela understands transformation as discrete events, all adding value to the product (barring defective work). Flow is seen as the chain of transformations inter-linked by

[3] These four classes of activities or process stages were originally introduced by the Gilbreths (1922)

other events such as inspection, transport and waiting, not adding value to the product.

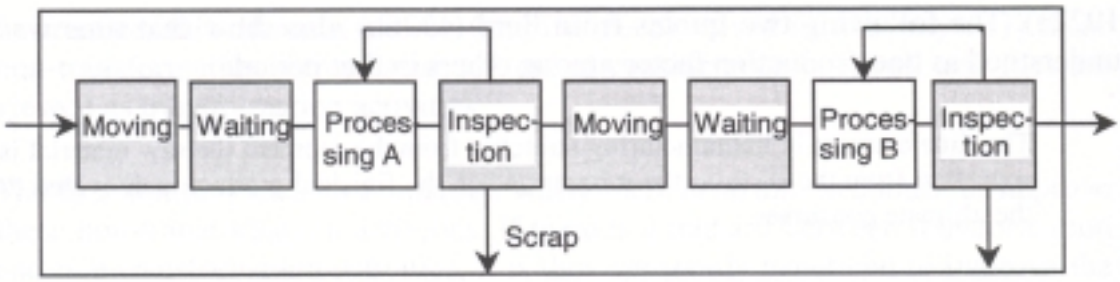

Figure 1: Production as a Flow as understood by Koskela (2000)

Shingo, on the other hand, explains production as a series of processes, each drawing on one or more operations. He claims that operations – the work undertaken by men and machines – and processes – what happens to the product along its travel through the production system, are phenomena lying on two different axes. Even though Shingo does not deal with value as a specific issue it can be said that in his view processes may be value adding or not, whereas operations are always just the carriers of costs. It may also be said that the Japanese understanding of the production as a value generation phenomenon is taken hand of through the design transforming the customers value perception into the product specification.

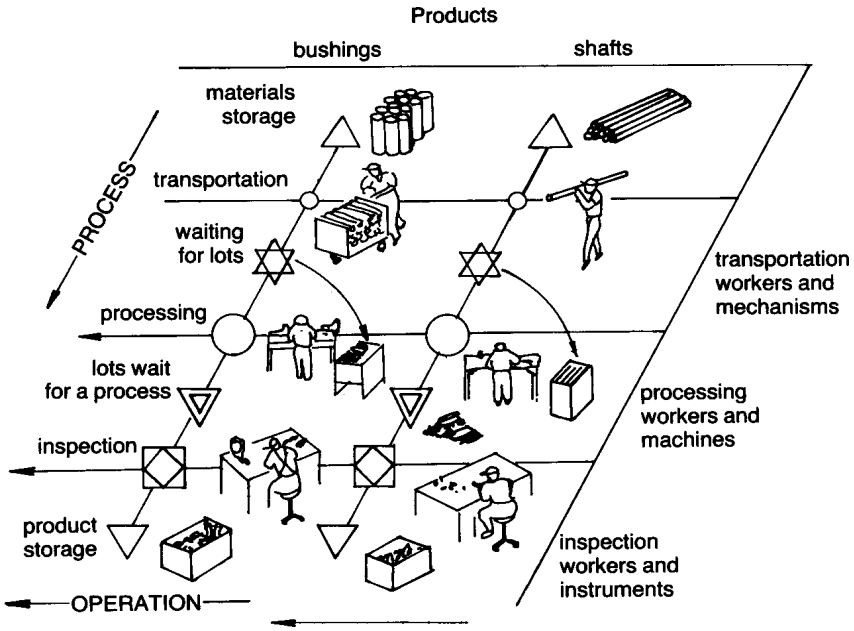

Figure 2: Production as Operations and Processes as understood by Shingo (1988)

Koskela's definitions are indeed the better in explaining the understanding of production from a historical as well as a theoretical and an economic point of view. But Shingo's may be more suited for the understanding of the nature of the construction process from an engineering viewpoint, and thus in understanding the nature of project management.The implications of this will be elaborated upon later.

MANAGING THE CONSTRUCTION PROCESS

Last Planner

The Last Planner approach to the planning and management of the construction process was introduced by Glenn Ballard at the first meeting in the International Group for Lean Construction – IGLC-1 in 1993 (Ballard 1993).

The principles were further elaborated upon at IGLC-2 in 1994 and by the paper: Lookahead Planning: the Missing Link in Production Control, presented at IGLC-5 in 1997 (Ballard 1997) the Last Planner system was complete as a useful tool to be introduced broadly in the construction process. (Bertelsen and Nielsen 1997)

The general idea is that in order to obtain an even workflow, a weekly work planning and a careful monitoring of the plan performance is needed. This takes place through the Last Planner, prepared at the site, as close as possible to the week in question. The Last Planner defines what *will* be done.

An important tool in the Last Planner toolbox is the Percent Planned Completed – PPC. PPC is monitored on a weekly basis and provides a measure of the plan reliability, which is an important prerequisite for the even workflow.

In order to ensure a sufficient workable backlog, the Lookahead Plan supplements the sliding window represented by the Last Planner. The Lookahead Plan is another sliding window looking 5-8 weeks ahead. This plan ensures 'sound' work packages, i.e. work packages for which all constraints are removed. The Lookahead Plan expresses thus what *can* be done.

Above these two plans lies a third – the Master Schedule – identifying all the work packages and their sequence for the job in question. This plan defines what *should* be done. The whole planning system is dealt with in detail in Ballard (2000).

Discussion

The Last Planner method has proven itself a very useful tool for the management of the construction process, and continuos monitoring of the planning efficiency through PPC gives rise to an ongoing improvement, which often ensures a steady stabilizing of the work flow and an improvement in the productivity. (Christoffersen et al. 2001)

The Last Planner thus stands as the landmark for lean projects and PPC as the signboard for posting the success of the implementation of the principles.

The Last Planner is developed as a tool for obtaining even workflow mainly. However, it may be more than that. Several other strategies in making the construction process more smooth and efficient seem to lead to the Last Planner principle as well. One example is the system for materials management developed in Denmark in the early 1990es (Bertelsen and Nielsen 1997), but also managing the flow of information seem to give rise to tools like Last Planner. Both experiences tie Last Planner nicely into Koskela's understanding of construction as a flow. Koskela (2001) looks at Last Planner from the perspective of language/action, small wins and Management-as-organizing and Management-as-learning. And recent Danish experiments (not yet reported) with self managing construction sites using multi-skilled gangs, as well as studies of safety and hazard on lean sites (not yet reported) point at the use of planning principles very similar to the Last Planner.

These observations raise the question whether Last Planner is a tool based on a generic characteristic lying deeper in the construction process. This characteristic may be

the complex nature of the project and of the system undertaking the process; a hypothesis dealt with in further detail in a later section.

LEAN CONSTRUCTION PRINCIPLES

Womack and Jones

The lean thinking was originally outlined by Womack, Jonés and Roos in their 1990 work and was further elaborated upon in the book *Lean Thinking* by Womack and Jonés (1996). The guiding principles were now coined:

- Identify the value stream
- Optimize the operations that generate the value
- Make the product flow, waiting is waste
- Use a pull logistic
- Seek perfection in all operations

Even though these principles have been very useful in the implementation of lean thinking in production as well as in construction, their validity can be discussed. For one thing, the principles do not focus on minimizing waste in all its forms, only on waste in the form of waiting. Also, waiting is not always bad. Certain buffers may be needed in order to optimize the throughput, as Goldratt has shown by his Drum-Buffer-Rope principle (Goldratt 1984, 1985). Also the workable backlog in the Last Planner system represents waiting.

But more important, neither Womack and Jones nor Goldratt focus really on the concept of generating value Their primary goal is reducing costs. This may be a valid strategy when looking upon the mass producing industry, but looking at project based one-of-a-kind productions such as construction, this is indeed a serious mistake.

Glenn Ballard

The validity of Womack and Jonés' formulation of the lean principles was challenged by Koskela (2000) who – inspired by the accepted doctrine of operations management – stated the objectives as: While getting the project done, maximize the value and minimize the waste. These objectives were further elaborated upon by Ballard et al. (2001) who divided the principles in a number of strategies and methods which can be used in the implementation of the lean principles not only in construction, but in any project delivery process

It is obvious that Koskela's formulation of the objectives is more precise and is covering more aspects as well. However, it omits a very important point in the Japanese thinking: the ongoing improvement, as expressed in the last of Womack et al's principles and also included in a number of Japanese inspired management theories such as Total Quality Management. As dealt with later: living in a world that is not perfect, one must always seek towards perfection without ever getting there. Thus it is here proposed that the lean principles should be:

While delivering the project, an ongoing effort should be made to maximize the value and minimize the waste.

This formulation of the objectives will be used as the guiding principles to bridge the gap between Koskela and Ballard.

Discussion

Even though the Last Planner can be linked to the theory of construction as a flow, which Koskela (1992) tries explicitly, some more views on construction may be useful in firmly bridging the gap between these two main contributions and in understanding the construction process' peculiarities. One reason for looking for such a deeper understanding is that the flow concept can not in itself explain the demonstrated success of planning with a short time horizon, as used in the Last Planner. Why not just plan in detail through the master plan and use that for the process control? Some deeper understanding of the construction process is needed in giving the reason for the fact that this system approach is not working.

Three such steppingstones between Koskela's TFV concept and the Last Planner are proposed in the following section in the format of construction as a one-of-a-kind-production; construction as a complex system; and construction as cooperation. Together with Koskela's three fundamental principles – TFV – these three new perspectives can be used to establish a new view on the construction process in general and its management in particular, as outlined in the last part of this paper.

THREE STEPPING STONES

CONSTRUCTION AS A ONE-OF-A-KIND PRODUCTION

Construction is a production of unique products. No two projects are alike. Not only are the projects different in their look and feeling, they are different in their details as well. Construction projects are not combinations of otherwise standardized details as found in the modern car production. They are products, which are different in any scale.

Construction is not the only industry that manufacturers a unique product. Movies and IT-systems both have much of the same uniqueness. But movies as well as IT-systems can be produced without the rigid assembly sequence that is another characteristic of construction. The development of IT-systems takes place as modules, which can be developed and tested as individual products before the final assembly. And any defect module can be replaced after the final system test.

Moviemaking has many of the same characteristics. A great part of the production can be made as a top down process, where the shooting takes place in a sequence best suited the production efficiency and the final assembly at the cutting table is carried out as a successive approximation to the final result. Even rework in the form of re-shooting a scene or two is possible within reasonable cost.

And both productions to a great extent take place in controlled environments such as studios or offices.

Construction on the other hand executes a production, which to a great extent is locked to a rigid assembly sequence, where the operations can not be interchanged. Furthermore, most of the production takes place in the haphazard and temporary environment of the construction site.

Only in the early design phases can construction make use of the top-down process best supporting creative work. While moviemaking and IT systems keep the top down process in operation almost until the final production stages, construction is forced to

abandon this approach before 10 percent of the process is completed. This means that the cooperation between the customer and the production team should be very close and well structured in the early phases. But unfortunately, such a close cooperation is the exception rather than the rule. Far too often is the drafting started without a detailed analysis of the client's needs and requirement for the work in question, and a diligent preparation of the design brief.

After the completion of the first design phases changes and rework are so expensive that they are commissioned only when really necessary – which they often are – and then with the associated high costs and delays as consequences. And even worse: changes and rework add substantially to the already great dynamic in the complex system which construction is.

CONSTRUCTION AS A COMPLEX SYSTEM

The understanding of complex systems is a science coming more and more into focus by the development of computer systems capable of simulating their behavior. More and more is it recognized that almost all living systems and most of the systems in society are complex and at the same time highly dynamic (Waldrop 1992).

The study of complex systems moves the focus from studying the elements in the system – the agents – to studying their connections and thus the network they form. By doing so, a great similarity between otherwise different systems can be found, from the system of cells in living organisms, to the anthill and the freeway traffic, and to the construction production system as well. By simulating such systems in computers their characteristics can be isolated and studied in detail, including how the strength of the interconnections influence the network behavior (Kauffman 1995).

It can be shown that such systems often exist on the edge of chaos, meaning their behavior is predictable in any detail only a few time-steps into the future. Whether the system shows this chaotic behavior depends on the situation, particularly how close the elements of the system are coupled. A well-known example of such systems is the weather being close to the edge of chaos.

The flow of traffic on a freeway system is another example. If the traffic becomes too dense, small disturbances in the traffic flow can release waves of traffic jam flowing backwards through the system and staying there a long time after their cause has disappeared.

Construction has many of these features as dealt with in more detail in Bertelsen (2002). The construction project is a sequence of coupled processes leading to the constructed artifact. The processes are all undertaken in the form of operations executed by men and machines provided by the trade contractors participating in the project. But these contractors all work on other construction projects at the same time as well, utilizing the same resources in all their contracts and thereby forming another closely coupled network across the project borderlines, and virtually to the whole construction sector in the district or even the country. Kauffman (1993, 1995) studies the nature of such networks in great detail and demonstrates that there need only be a few couplings from each node to randomly chosen other nodes before the whole network acts as one. The transition from individual nodes or small clusters to a whole takes place almost suddenly, when the number of couplings is increased, just like a phase transition.

Not only is the workflow through the network of activities for the project in question uncertain, because only the value generating processes are mapped, omitting the

inspection, transport and waiting processes in between. But also the couplings to the resource networks are totally unknown and ever changing. These couplings are certain to be tight because of the agents' efforts to maximize their resource utilization and the dynamic in the whole network is great as well, because of the fluctuations in workflow.

The construction activities within an economic system are not independent processes, but form one big system operating on its own without any over all management. Any attempt to establish such management is deemed a fiasco – the system will freeze and all processes almost certainly stop.

Brousseau and Rallet (1995) point at the construction industry's peculiarities, lack of a formal management being one of them. Also Tavistock (1966) puts focus on the unusual form of management found in construction compared to manufacturing practice. Looking at construction from a complexity point of view makes this peculiarity quite natural. Highly complex system can not be managed by a formal management approach, but must be given a high degree of freedom to organize and manage themselves – order for free, as Stuart Kauffman (1993) coins the phenomenon.

Goldratt (1984, 1985) presents a method for the management of a production system consisting of shared resources for several products called the drum-buffer-rope principle. Goldratt looks at a closed system within one economy only though, whereas construction forms an open system guided by a multitude of economies. It seems that construction must learn how to live with this chaotic situation.

As in many complex systems of this kind, the same patterns can be found in the details as in the whole. The complexity of the whole construction sector can – on a smaller scale – also be found within the project and even down in the individual task. This makes any long-term predictions about the execution of the work next to impossible, no matter how advanced tools are brought into operation.

However, this phenomenon is not understood by the industry. Project management is based on the assumption that construction is an ordered system, which can be planned in great detail and executed in all details according to the plans. The result is well known: the plans are not followed, and closer investigation reveals that there exist a number of unofficial and unauthorized management systems to ensure that the work gets done (Tavistock 1966).

CONSTRUCTION AS COOPERATION

Looking at the construction process as the phenomenon it really is: a complex production of a one-of-a-kind product involving big capital investments, the organization and management comes into focus. What happens at the construction site can be seen as a production in a virtual company.

A production takes place and people meet to undertake it. *But they do not do so as a production company!*

The construction process has none of the characteristics of the modern manufacturing company. Sub-optimization is found everywhere and nobody has the over all success of the production as their personal success criteria.

The form of cooperation found in construction has long since been given up by other industries, even the army. Orders and dress downs and only limited respect for the professionalism and the work of others are the rules in construction. The result is everybody’s fight against everybody, where the project management is forced to take the

role as the umpire, adhering to the formal rules instead of establishing an efficient, common company culture.

The temporary nature of the project makes it further difficult to establish a positive cooperation. In systems where cooperating as a whole is to the benefit of all, but where bigger benefits can be gained for the individual by cheating, the temptation to cheat becomes great, when the participants know that the cooperation has a limited duration. Particularly so towards the end of the cooperation (Thomassen 1999).

And the construction process is just such a situation. Everybody is here for a short duration and each has his own business to attend to. As an individual or as a trade contractor. And nobody tries to generate team building and cooperation. Just the opposite. Even the management stands on their rights and on the contractual details without any concern for the real benefit for the project. No wonder things are as they are!

That things are bad may be hard to prove. But experiments with new forms of cooperation and a new management style almost immediately show a better performance through a more efficient process (Christoffersen et al. 2001).

DISCUSSION

Looking at the Last Planner system in the light of these three new views may lead to a deeper understanding of why the system is so useful in practice. The one-of-a-kind nature of the project makes it very hard to establish a reliable production schedule. Too many things are uncertain and these uncertainties add up along the chain of activities as shown by Koskela (1999, 2000). The short horizon for the planning of 'will do' is thus an elegant way of overcoming this uncertainty aspect.

The same goes for the complex nature of the construction process and industry. Complex systems often show a high sensitivity to initial conditions making them in practice unpredictable for more than a few steps into the future. The feature is often referred to as *chaos.* From this aspect Last Planner can be seen as the establishment of a local window of order in an otherwise chaotic situation.

Finally, Last Planner can be seen as a means for establishing a co-operation between equal parties at the construction site. The planning process executed as action learning supports the cross trade cooperation and brings a mutual understanding of the importance of an even work flow to 'the men on the scaffolding.'

These interpretations of Last Planner seem to support the hypothesis that Last Planner is a tool reflecting the generic nature of the construction process.

THOUGHTS ON PROJECT MANAGEMENT

Having established a theoretical understanding of the process and its nature, an operative wording of its objectives and a value oriented process model, it seems natural start looking at the management of this system.

Several authors have shown that the traditional management of the construction process is very poor. Indeed, it has been said that the construction management is the management of contracts only (Koskela and Howell 2002).

Recent experiments with a divided project management, where the management of contracts (or operations) are separated from the management of the process, and where a separate management of the value generation have shown remarkable results in the form of improved production, shorter production time, lower costs, increased workers' safety and a higher client's satisfaction (Christoffersen et al. 2001). It is the author's feeling that

many of the characteristics of this new kind of project management can also be found in most of the successful implementations of the lean principles in other countries, even if they are not recognized and formalized as in the Danish implementations. Bertelsen and Koskela (2002) looks deeper into project management along these lines.

FUTURE RESEARCH

The above outlining of the lean landscape as shown from a Danish viewpoint calls for a future research besides the mainstream IGLC work.

One important issue is the understanding of construction from a complexity point of view – a completely new and very challenging approach. This will inevitably bring the co-operation between the participants in the form of an integrated but temporary human system – not least the cooperation on the workers' level on the construction site – into focus as well. Modern management theories such as management as learning and management by walking around should be considered in the context of managing the construction process.

Project management should be studied in a broader context as well, not least value management. Value is a personal and situational parameter. The understanding of its meaning in the light of the construction project as a complex system generating artifacts with an expected long lifetime, several users and huge impact on our build environment, is of paramount importance for the proper implementation of value management. At the same time, experiences for the ongoing Danish experiments with the form of project management should be reported and analyzed from a theoretical point of view.

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