# CONSTRUCTION BEYOND LEAN: A NEW UNDERSTANDING OF CONSTRUCTION MANAGEMENT

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## ABSTRACT

Lean Construction has existed in its own right for more than ten years. At the same time the five lean principles as outlined by Womack and Jones have gained a firm foothold in the manufacturing industries, and the term *lean* has thus become a household term in manufacturing. Unfortunately and confusingly, the understanding of *lean* has taken very different trajectories in these two communities. In manufacturing, it is often voiced that the (five) lean principles provide a mature understanding of the subject, i.e. the end point. However, in the same time the theory based understanding of construction management has moved beyond the generic lean theories and principles, embodied in the Toyota Production System, to encompass disciplines such as complexity, emergence, conversations, and lifelong learning. In construction, the Toyota Production System is thus rather a starting point. The paper establishes an overview of the principles guiding best practice project management today, and argues that lean construction has progressed beyond lean – at least in the sense propagated by Womack and Jones.

## KEY WORDS

Construction, management, lean, production

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## INTRODUCTION

This paper tries to establish the basic ideas of Lean Construction as we see them after twelve years' work, resulting in more than 300 papers presented in peer reviewed journals and conferences along with a dozen research reports and dissertations.

The paper sets out by pointing to the fact that the *lean* concept in general is a western interpretation of the Japanese production philosophy. It then extracts some fundamental principles from the works of Shigeo Shingo as one part of the basis for Lean Construction.

It proceeds by establishing a new understanding of construction as a special kind of production, which in its nature is very different from that found in manufacturing, which was the basis for the work of Womack et al, and by that it identifies and analyses the concepts behind Lean Construction. It concludes by outlining some of the principles and methods this has brought to our understanding of new management of construction.

In doing this, the paper shows that *lean* as defined in the manufacturing management literature is not the basis for Lean Construction any longer.

## DEVELOPMENT OF LEAN CONSTRUCTION

Lean construction principles and practice have been examined and developed in two interacting research streams.

The practical stream started with Howell and Ballard's (1995) observations that typically only half of the tasks in a weekly plan get realized as planned on site. In a series of experimental work, a new approach to production control, called the Last Planner™ System, was developed (Ballard 2000). Whilst Last Planner covers production control and improvement, methods for production system design have also been developed (Ballard et al. 2001). Furthermore, various new practices for different aspects of design and construction management have been developed (Bertelsen and Koskela 2002, Bertelsen et al 2002, Christoffersen 2003).

The theoretical stream started with Koskela's (1992) analysis of the application of the new production philosophy to construction. The question is about the interpretation of generic principles of operations/production management. Others (dos Santos 1999) have examined the validity of these principles in the production situation of construction. In (Koskela 2000) the discussion on the principles was deepened and theoretical explanation for the principles was presented, based on current theories in operations management. While this work addressed primarily the theory of production, research on the theory of management was also embarked on, especially in the context of project management (Howell & Koskela 2000, Koskela & Howell 2002) and for explaining the underlying principles of the Last Planner system. Furthermore, the issues of complex adaptive systems have been addressed (Bertelsen 2002, 2003a and b). Growing interest towards exploring the theories of inherent social and psychological functions in production and its management, such as cognition, communication, learning, decision-making, etc. can be perceived (Macomber and Howell 2003).

These theoretical and practical developments are put into context later in the paper.

## LEAN THINKING

Lean Production was coined by Womack et al (1990) to describe the implementation of the ideas inherent in the Toyota Production System. It was based upon their studies of the car manufacturing industry in Japan and other countries.

Womack and Jones (1996) moved from the automotive industry to look at manufacturing in general and established the five principles for Lean Production; this theoretical foundation is called Lean Thinking by them:

1. Precisely specify value by specific product.
2. Identify value stream for each product.
3. Make value flow without interruptions.
4. Let the customer pull value from the producer.
5. Pursue perfection.

Even though these principles are stated more broadly in the 1996 work, they are coined more precisely in later guidelines for their implementation (Rother and Shook 1999).

However, in the second edition of Lean Thinking (Womack and Jones 2003), these five principles are presented in an unchanged form – actually, the authors "have been careful not to change the pagination". Factually, the idea that these principles have reached their final form has recently been endorsed in operations management literature (Slack et al 2004): "For instance, JIT/lean production is a long-established OM research priority that in recent years has probably become less prominent as a subject as the core principles have matured. In terms of practice however, there is still a great deal of scope for applying these, now clearly articulated and tested, principles – especially beyond their traditional manufacturing roots (e.g. Womack and Jones, 1994, 1996)".

The five principles make it obvious that the optimization of the flow – of value towards the costumer – is the guiding principle. The three middle principles focus directly on this, whereas the first and the fifth can be seen as general objectives. The principles have thus derived from an ordered situation with a well known product and costumer base, a production process that is precisely defined and a well established supply chain. Not an unusual situation in manufacturing, and the principles have also proved themselves valuable in increasing productivity in several western manufacturing industries and are thus very useful. But that does not at all prove their usefulness for a special kind of production such as construction, because their use should then be argued by showing that construction is a production similar to manufacturing, which it indeed is not.

To this comes that the five principles are not the whole lesson learned when studying Japanese sources such as Shigeo Shingo and Tai-ichi Ohno. Unfortunately the most read of the two is Ohno (f.i. 1988) and his work is inspiring but not very specific. Shingo, on the other hand is very specific but do not provide management principles in the form Western managers seem to prefer them. This may be one reason for Western managers seeing Lean Production principles as the essence of the Japanese understanding of production.

Furthermore, it must be added that the five principles have not been invented by Womack and Jones, but rather they[3] have been present in earlier Western interpretations, for example, by Schonberger (1982, 1986, 1990, 1996).

Thus, bizarrely, the five principles of Lean Thinking seem to be positioned as the end point of the theoretical progress of lean manufacturing, even if they can hardly be claimed to be complete or original.

### SHINGO REVISITED

Shingo (1988) considers minimizing waste as the central element in the development of the manufacturing process – even though his books are titled non-stock-production or similar. The value generation, on the other hand, plays only a minor role in his thinking. Indeed, the term *value* is very hard to find in his works.

Single piece flow is his strategy in obtaining minimal waste because this forces the system to make no errors and to be flexible. Consequently SMED[4] is a central issue for Shingo. Stock on the other hand is a phenomenon, which can be seen as waste, but – more importantly – is considered a narcotic, hiding errors in the process flow. This is contrary to the Western thinking where a certain amount of stock is accepted as a buffer, offering protection against the flow variation.[5]

Shingo also puts emphasis on the involvement of the individual worker in solving process problems and undertaking product inspection – poka yoke – just as communication between workers along the process line is seen as a means for improving the flow of work. This can be seen as the recognition of the process not being totally ordered and foreseeable and that the approach to this should be cooperation and learning.

Womack et al. and most other contributors to the Western theories of production take the approach that they are dealing with an ordered and in principle foreseeable process[6]. Hopp and Spearman (2000) demonstrate this thinking in putting the manufacturing process' elements into a fairly sophisticated mathematics, where flows and buffers can be designed in principle with an outset in the expected variation. This may be valid for manufacturing, but the next section demonstrates that the assumption that the process is ordered may not at all hold true in construction – just as Shingo recognized in manufacturing – and that Lean Construction as we see it today represents a complete and radical new, theory based understanding of the special kind of production called construction.

## WHAT KIND OF PRODUCTION IS CONSTRUCTION?

Construction is obviously a production, and Koskela (2000) establishes a theory for production and demonstrates its use in construction. The basic idea is that construction should not be seen as transformation only but understood as a flow of work and a creation of value as well.

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[3] With the exception of the first principle, whose essence seems to have been first presented by Levitt (1960).

[4] Single Minute Exchange of Die

[5] This goes for Last Planner ™ as well.

[6] By Womack and Jones, this is especially evident in the paucity of discussion on product design, which is an inherently unordered stage of the total production cycle.

Factory Physics in general (Hopp and Spearman 2000) along with Womack et al and Shingo all understand production as flow as well as (at least implicitly) transformation. However, they all see the flow as laminar[7], albeit with small eddies. These are either considered as errors that should be corrected (Shingo 1988) or as unforeseeable events, which should be handled by buffers, which should be kept as small as possible (Hopp and Spearman 2000, Womack and Jonés 1996). In contrast to this, construction is indeed a true turbulent kind of production and should be managed as such (Bertelsen 2003a and b, Bertelsen and Koskela 2003).

In understanding the nature of construction it should also be recognized that construction makes one-of-a-kind products and do so on the site by cooperation within a multi-skilled ad-hoc teams.

A general definition of the nature of construction from a production point of view may thus be:

> *Construction is a complex production of a one-of-a-kind product undertaken mainly at the delivery point by cooperation within a multi-skilled ad-hoc team.*

The above definition of construction indicates at least four characteristics. Construction is *production* and it produces a *one-of-a-kind product*, it is also *complex* and undertaken through *cooperation*.

The next sections deal with the impact of these characteristics on lean construction and on construction management.

## CONSTRUCTION AS PRODUCTION

### MANAGING PRODUCTION

Koskela (2000) introduces three basic conceptualizations of production: transformation, flow and value generation. Bertelsen and Koskela (2003) consider these three aspects from a management point of view as outlined in the following.

#### Managing Transformation

Managing transformation is the kind of project management most project managers are familiar with. It takes place by managing contracts, establishing quality and safety requirements and procedures, and it frequently leads to what seems to be an increase in productivity but in truth is sub-optimization only.

It is necessary to manage the transformations in construction if for no other reason than because of the huge contract values involved, but this simplistic kind of project management is not adequate in the complex and dynamic system the project usually represents.

#### Managing Flow

Managing flow in the construction industry introduces several new management activities. One should be to establish a closer cooperation along the supply chain – Supply Chain Management has this been coined in the manufacturing industry. This kind of cooperation should not only comprise cooperation between main contractor and trade

[7] In physics, the term "laminar" refers to a flow without eddies as opposite to "turbulent"

contractors, but should comprise the manufacturers and suppliers of construction materials as well. Another activity should be setting up the logistics for materials and information.

Bertelsen and Nielsen (1997) report the effects of such procedures in practice and Vrijhoef and Koskela (1999) investigate the aspects from a management point of view. The method of Last Planner (Ballard 2000) can also be seen as an important tool in managing this cooperation and the logistics during the construction phase.

### Managing Value Generation

The concept of value is probably the most difficult to approach in the new way of managing construction projects. Green (1996) proposes an understanding of the value generation during the early design phases as a learning process between the client and the design professionals. Both parties learn and through this a joint understanding of client's value parameters and their realization in the design is reached.

Christoffersen (2003) reports the successful implementation of a systematic value management as proposed by Bertelsen et al (2002) in order through the project life cycle to make sure the specified value is delivered, whereas Green (1996) introduces value engineering as the task of generating the specified value with the lowest costs.

## ONE-OF-A-KIND PRODUCTION

One-of-a-kind production makes it necessary to integrate the design and production processes. The unique product makes in the later process phases the flow of information just as important as the flow of materials and equipment, which adds substantially to the project complexity.

Bertelsen et al. (2002) proposes a new process for this where a great part of the conceptual design is performed through a series of workshops and where a greater number of the client's stakeholders – often as many as thirty to forty – are involved in the cooperation with the designers in day long sessions. Christoffersen (2003) reports how this approach in practice has led to a shorter and more efficient design process with a substantial higher customer satisfaction and fewer project revisions in the later phases.

The reason for these remarkable results is quite obvious when interpreted through the complexity thinking. Complex systems may give raise to wicked problems and wicked problems should usually be solved by consensus between as many stakeholders as possible. The workshop is the setting for this kind of problem solving and project revisions are reduced by the stakeholders taking ownership to the design solutions.

In recent years partnering as a value generating cooperation in project production has gained more and more foothold at least in Danish construction projects. Most arguments for this kind of cooperation have been that the number of claims is reduced, but the experiences with the workshop approach may be a new argument for the use of partnering in the conceptual design phase: it is a more efficient way of generating project value.

## CONSTRUCTION AS A COMPLEX SYSTEM

Lean Construction's own new dimension in understanding construction as a production is that it is a complex and dynamic system. Bertelsen (2002) introduces this new thinking as basis for a new understanding of the nature of construction management.

## Complexity in Construction

Generally, project management understands the project as an ordered and simple – and thus predictable – phenomenon which can be divided into contracts, phases, activities, work packages, assignments etc to be executed more or less independently. The project is also seen as a mainly sequential, assembly-like, linear process, which can be planned in any degree of detail through an adequate effort and executed in accordance with the plans. As a consequence, project management acts top down, mainly by management-as-planning as proven by Koskela and Howell (2000). The plans and schedules present an idealized linear picture of what *should* take place, but not of what actually does take place. Planning does not reflect reality, but dreams!

This paper proposes that the perception of the project's nature as ordered and linear[8] is a fundamental mistake, as the dynamics of the surrounding world is not taken into account. Project management must perceive the project as a complex, dynamic phenomenon in a complex and non-linear setting.

Most systems in the world are complex. And so is construction (Bertelsen 2003a). This can be seen already in the wicked nature of the building design process, which is caused by the fact that there is no optimal solution to the problems faced, and where preconditions are defined in parallel with the solutions. Very often the results of this complexity of the design process overflow to the next stage, construction, in the form of delays, deficient information and poorly constructible design solutions.

However, the same kind of wickedness is often found in the construction phase, which is characterized by the close succession of

- production system design,
- production system realization,
- operation of the production system and
- dismantling of the production system.

Thus, the possible, and in practice frequent, problems in production system design and realization get inevitably entangled with the operation of the system. Note that in manufacturing, production system design and realization are infrequent events, and the focus is on the operation of the production system in the framework of a stable, existing production system.

A further complication in the construction stage is that when the production system is temporary, there are usually several projects competing for the resources of any subcontractor (O'Brien 1998). Thus, disturbances in one project are easily transmitted to other projects. This phenomenon exists also in the design stage.

A construction project may look like a sequential assembly-like process, and so it is in a distant perspective. But in detail, the process is highly parallel. Many project activities are not inter-dependent and may be executed in any sequence or even simultaneously without any effect on the over all result. Starting from the bottom, it is up to the individual craftsman to choose his way of doing the job at hand. No formal process description is normally provided, and the industry practice of not interfering across contractual boundaries with the way work has to be carried out, enhances this informality

[8] The term"linear" is used here as a characteristic of the mathematical functions describing systems without feed back loops, f.i. Newtonian systems.

in the low level process design. But also at higher levels is the process not sequential. The trade contractor may have his own way of executing the job. The weather may change the sequence, and unforeseen events may enforce further changes in the sequence, which to a great extent can be made without any impact on the general schedule. This potential for non-sequential progress is used for buffering the variability caused by the complex nature of construction, although often further problems are simultaneously created (Koskela 2004a).

The different stakeholders participating in the construction process have different targets and objectives as well, but have to collaborate in order to complete the project successfully. Compromise is the way ahead in great many cases.

**Managing Complexity**

Complex systems offer a series of characteristics, which are not found in ordered systems but should be taken into consideration in project management. Bertelsen (2003b) considers these characteristics and analyzes construction in three perspectives in the light of eighteen such characteristics taken from an overview compiled by Lucas (2000).

From a project management point of view, some of these characteristics are of particular importance. Among these are *emergence* – the system as a whole shows characteristics that may not be deduced form studies of its elements, *self organization* and *self modification* – the system is able to create order and change itself, upward and downward causation – the system is affected by its element jus as the elements are affected by the system's over all state as well as unpredictability – the future state of the system can not be predicted in any detail. Bertelsen and Koskela (2003) consider this last aspect in construction.

As complex systems are in their nature unpredictable but capable of self organization and learning, management of such systems can not be based on detailed instructions or plans but must comprise a statement of the objective, improvement of reliability and distributed control. (Kelly 1994) Such management principles can by found in practice at for example the US Marines (Fredmann 2000). From a construction management point of view this leads to a new management principle: management-as-cooperation and learning.

**Managing Cooperation and Learning**

Management of complex systems requires a different approach than managing ordered systems. Whereas ordered systems can be managed in accordance with plans, complex systems are unpredictable in their behaviour and must thus be managed with an outset in actual state of the system. This understanding leads to a bottom-up management based to a great extent on cooperation and learning in accordance with the complex system's developing and self organizational capabilities. Macomber and Howell (2003) introduce this understanding of management as a conversation with an outset in Flores (1982) and they thereby introduce linguistic action in the Lean Construction body of understanding.

This understanding makes the project management understand plans as commitments or as deals between parties otherwise equal, and the importance of being able to make and keep reliable promises comes into focus in construction management. Macomber (2001) deals with this type of management and his principles have been used in the recent implementations of Lean Construction in Denmark (Bertelsen et al 2002).

The learning aspect has recently been taken even further as it is now seen also as development of competence i.e. that capability of doing the right thing at given moment. This idea was the basis for the recent reported Danish experiment BygLOK[9] (Elsborg et al 2004), and the understanding of project management as management-as-learning, where delegation of responsibility, cooperation and learning should be central principles, is now being used in practice in the recent Danish initiative: Lifelong Learning in Construction – Byg*SoL* (2004).[10] This initiative has been taken by parties within the industry and funded partly by the European Social Foundation and partly by the industry itself. Its aim is to develop and implement a new construction process yielding higher value and lower costs.

## CONCLUSION

The movement of Lean Construction away from the manufacturing interpretation of the lean concept has led to several new management approaches.

While the transformation-flow-value theory broadens the understanding of project management, the perception of construction as a complex phenomenon opens up for the introduction of completely new approaches to project management. The ordered approach which gave rise to what can be called management-as-planning and management-as-organizing should be reinterpreted and supplemented in future project management. Management as co-operation and as learning comes into focus[11]. Indeed a huge challenge!

Even though some of these new principles to a certain extent are ideas only, all of them are to a certain degree being used in practice within front end implementations of Lean Construction[12].

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[9] The abbreviation stems from the program's name in Danish: <u>L</u>æring, <u>O</u>rganisation og <u>K</u>ompetence i <u>Byg</u>geriet

[10] The abbreviation Byg*SoL* stems from the initiative's name in Danish: <u>S</u>amarbejde <u>og</u> <u>L</u>æring i <u>Byg</u>geriet.

[11] Bertelsen (2003a and 2004) proposes such supplements as management-as-teambuilding, management-as-service providing, and even management-as-a-nuisance.

[12] However, this opens the question whether this is within the North European implementations only or whether the principles are generally applicable?

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