LEAN CONSTRUCTION AS A MOVEMENT TOWARDS THEORY-BASED CONSTRUCTION MANAGEMENT

L. Koskela
The University of Salford, School of Construction & Property Management
Salford M7 1NU, United Kingdom
E-mail: l.j.koskela@salford.ac.uk

ABSTRACT: It is contended that construction management faces a triple task: taking the step from implicit to explicit theory; pinpointing and assessing the present implicit theory for being able to unlearn it; advancing a new explicit theory, learning it and making use of it. These three issues are discussed in turn. The justification and benefits of the step from implicit to explicit theory are discussed based on the influential work of Kuhn on scientific paradigms. It is contended that much, although surely not all, of the present implicit theory, can already be pinpointed, and the associated counterproductive impacts explained and empirically recognized. The new theoretical foundation of construction management is shortly discussed based on recent work in the framework of the lean construction movement.

Keywords – lean construction, theory

1. INTRODUCTION

In their recent book, Loosemore et al. (2003) pinpoint to lean construction as a management fad, comparable to TQM (Total Quality Management) and BPR (Business Process Re-engineering). They are critical regarding overuse, abuse and misuse of such managerial fads, their origins in manufacturing, their compatibility with the engineering mind-set, and "the almost obscene levels of hype and expectation which surround them". They agree with the view that "the dogma, platitudes and grossly biased claims associated with many current management trends foster superficiality". What comes to lean construction specifically, Loosemore (for brevity, the name of the first author is used to refer to the whole author team) views that the unconsidered application of lean thinking to all operating areas could be highly dangerous, as construction is already operating too leanly. As a justification to this claim, Loosemore presents the example of Australia, where most operatives regularly work a 60-hour week, which produces safety hazards and other problems.

As far as the present author knows, the term "lean construction" was coined in association to the founding of the International Group for Lean Construction (IGLC) in 1993. After that, a growing community of researchers have advanced a concept of lean construction (Koskela 2003) that is totally different in comparison to Loosemore's characterization. Indeed, going back to 12-hour working days, as implied by Loosemore's warning, is not known to have been suggested in any presentation on lean construction. As the mentioned book gives the impression that its authors are not aware of the IGLC community and conversations conducted within it, it is opportune to respond to the claims and concerns presented in the book.

The main tenet of this paper is to show that lean construction represents a movement to theory-based construction management. It is contended that construction management is in some ways proceeding through a similar period as experienced by structural mechanics in the 19th century, when the classical theory of mechanics matured. Whilst previously the design of structures had been carried out based on rules-of-thumb and experience, so after the maturation of the theory, designs could be based on theory-based calculations. In consequence, structural collapses became increasingly rare.

However, in contrast to structural mechanics, construction management is not in a situation of a lacking foundational theory, but rather it has been based on implicit, but unfortunately to some extent counterproductive, theory. Thus, construction management faces a triple task: taking the step from implicit to explicit theory; pinpointing and assessing the present implicit theory for being able to unlearn it; advancing a new explicit theory, learning it and making use of it. These three issues are discussed in turn.

2. FROM IMPLICIT TO EXPLICIT THEORY

It is easy to agree with Harriss (1998): "If anyone has formulated a theory of construction management, they have kept it a closely guarded secret." There simply has not existed a theory of construction management, which would be solemnly presented in the beginning of text books. However, construction management is in good company: this same situation also prevails in the closely related, but wider disciplines of project management and production/operations management.

Is this lack of theory a problem? Several answers have been proposed to this question. Recently the view has been presented that the progress of construction is mainly dependent on innovations in other industries; thus technology transfer accentuates, rather than theory formation (Fairclough 2002). For some, construction management refers to an object of study that should be approached from a variety of disciplinary angles. Thus, the theories of economics, social science and law are used to bear on construction management, which thus has no theory of its own or cannot have it (Runeson 1997). Another opinion, voiced in the context of operations management, holds that the question is just about theory envy (Schmenner & Swink 1998) – a psychological problem. Yet another standpoint, cultivated regarding project management, says that the relevant knowledge is so contextual that there never can be objective theory of project management (Morris 2002).

Even if space limitation prevents from encountering each listed answer in detail, we rather contend that a lack of theory has been and still is a serious problem in construction management. This view follows from the recognition that a theory has several functions in the scientific endeavour (Koskela 2000), and is thus a focal point of the scholarly effort. A theory provides not only for explanation and prediction, but also gives direction for further research efforts as well as subjects itself for testing of validity. In addition, a theory has several application-oriented functions, such as providing a basis for decision and control.

Let us consider one function in more detail: giving direction for further research efforts. According to Kuhn (1970), the progress of science is characterized by two distinct models of inquiry: normal science and scientific revolution. Normal science, guided by shared theories, a shared paradigm, is highly cumulative and successful. After the potential of a paradigm has been exhausted, a period of paradigm change, scientific revolution, will follow. However, a discipline may also be in a situation where no commonly accepted theories have yet emerged – it is in a pre-paradigm phase. Kuhn describes the pre-paradigm phase of a science as one where individuals practice science but the results do not add up to science, as we know it. This is, according to Kuhn, because facts collected with little guidance from pre-established theory seldom speak with sufficient clarity. Characteristic for the pre-paradigm phase is also that there are competing schools which interpret the same facts differently. Research effort is slowed down in this phase also by the need, in major works, to build the field anew, starting from the first principles. It is only through the emergence of a paradigm, a shared theory, which starts the highly effective phase of normal science.

Given the lack of shared theory, it is appropriate to characterize construction management as a discipline in the pre-paradigm phase – or at least approaching it. Namely, Betts and

Lansley (1993) find in their review of construction management literature little evidence of approaches to research that are clearly driven by, or contribute to, theory. Thus, it could be asked whether there has been much pursuit of scientific progress in construction management at all. Anyway, the scientific progress of construction management is doomed to be slow, or even negligent, as long the pre-paradigm phase dominates.

Among managerial sciences, the quest for a paradigmatic theory is not a phenomenon restricted to construction management. Rather, a similar movement is emerging in the wider fields of operations research and management science (Saaty 1998). The focus is shifting from individual problems to a theory of the system where the problems are embedded. The characterization of this shift, presented in this wider context, is perfectly adequate also regarding construction management (Saaty 1998):

> After more than a half century of tinkering with and solving problems, we need to characterize the system underlying our activity, classify, and generalize its problems.

3. WHAT IS THE CONVENTIONAL THEORY?

3.1 Towards a theory of project management and associated fields

The theoretical foundation of project management can be divided into a theory of project and a theory of management (Koskela & Howell 2002a, Koskela & Howell 2002b). An overview is presented in Table 1.

The theory of project (or production) is provided by the transformation view on operations. In the transformation view, a project is conceptualized as a transformation of inputs to outputs (Koskela 2000). There are a number of principles, by means of which a project is managed. These principles suggest, for example, decomposing the total transformation hierarchically into smaller transformations, tasks, and minimizing the cost of each task independently.

The understanding of management is based on three theories: management-as-planning, the classical communication theory and the thermostat model (Koskela & Howell 2002a). In management-as-planning, management at the operations level is seen to consist of the creation, implementation and revision of plans. This approach to management views a strong causal connection between the actions of management and outcomes of the organization. In execution it is assumed that planned tasks can be carried out by a notification of the start of the task to the executor. Such one-way communication is covered by the classical communication theory. The thermostat model is the cybernetic model of management control that consists of the following elements: there is a standard of performance; performance is measured at the output; the possible variance between the standard and the measured value is used for correcting the process so that the standard can be reached.

Table 1. The underlying theory of project management

Subject of theory		*Theory*
Project		Transformation
Management	Planning	Management-as-planning
	Execution	Classical communication theory
	Control	Thermostat model

However, there are a considerable number of hidden assumptions in the underlying theory of project management (Koskela & Howell 2002b). Many of these assumptions are valid only in exceptional situations. These wrong assumptions lead directly to several kinds of problems in practical project management. Those problems are thus self-inflicted, caused by the very theories and methods we are relying on.

One illustration of the wrong assumptions is provided by the treatment of uncertainty, which is not explicitly represented in the transformation model. Consequently, the prescription of project management does not contain principles for handling uncertainty or possibly decreasing it (except possibly a separate risk management exercise). This is in stark contrast to the implications from another, queuing theory based understanding of operations, where the reduction of variability is a fundamental principle (Hopp & Spearman 1996).

3.2 Counterproductive impacts of the transformation model in manufacturing

The phenomenon of self-inflicted problems due to the transformation model is well documented in manufacturing. According to Schonberger (1996), there was a constant decline of productivity in the American manufacturing industry in 1950 – 75, manifested in the constantly increasing amount of work-in-progress. Other empirical research has verified that the amount of work-in-progress is inversely related to efficiency (Holmström 1995).

This phenomenon can be associated to a progressively deepening application of the transformation model, and the resulting suboptimization at the level of units, departments, etc. Unfortunately, the more we try to optimize each part individually, the less we pay attention to the co-operation and synergy between those parts. In manufacturing, this is concretely visible in the form of growing material piles between workstations and departments, caused by the objective of achieving a high utilization rate. Thus, after decades of counterproductive application of the transformation model, the absurdity of the situation was at last recognized around 1975, and apparently methods based on other theories were increasingly turned on. The performance started to increase again.

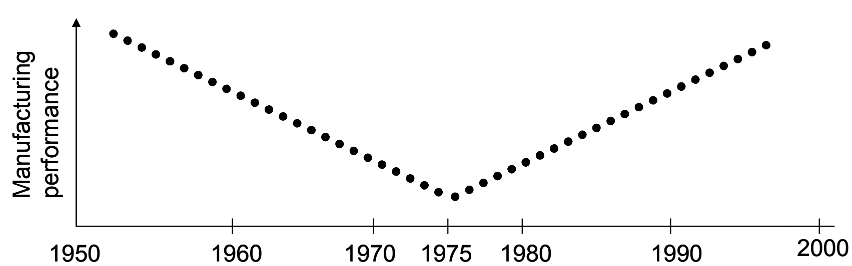

Figure 1. The schematic pattern of manufacturing performance in 1950 – 2000 (Schonberger 1996)

3.3 Counterproductive impacts of the transformation model in construction

Has there been a corresponding situation in construction? It can be argued that a similar phenomenon of self-inflicted problems due to the transformation model can be perceived, at least in some countries' construction industries. However, there are two major differences to the case of manufacturing. First, instead of the pursuit of high utilization rate, in construction the transformation model leads to buying the future execution of each task on the basis of the lowest price. This has several consequences, among others: (1) the total design effort tends to decrease, (2) the production control effort tends to decrease. Second, the resulting problems do not become visible as work-in-progress, but rather as the opposite of work-in-progress, which may be called *making-do*. Let us discuss these phenomena in more detail, along with an empirical illustration.

3.3.1 The transformation model and its behavioral consequences

The first principle of the transformation model suggests decomposing the total transformation hierarchically into smaller transformations, or tasks, and minimizing the cost of each task independently (Koskela 2000). In construction, this equates to buying the execution of each task on the basis of lowest price. However, this more or less directly leads to two major problems, at least. First, in case of design, where it is difficult to assess the completeness of design drawings, the total design effort, and consequently also the quality of design and documentation tend to decrease. Second, regarding construction site, the cost of each contract being fixed in advance, production control tends to degenerate into contract control, as it has been previously argued (Ballard and Howell 1998).

It is not difficult to find empirical evidence for the predominance of the transformation model and its implications in construction. The appearance of this paradigm is aptly described in the following quote (Butler 2002):

> I've seen a lot of changes in the construction industry in the past 30 years. Construction systems have become more and more complicated. Disciplines have divided and subdivided and whole new trades have sprung up. The whole concept of the general contractor, like the master architect, is becoming a thing of the past. When was the last time you had a project that didn't have a project manager, a project engineer and a superintendent? Did any of them do anything more than push paper? Did any of them walk the jobsite to make sure that the folks with the hammers and nails weren't putting holes in the roof?
>
> Today's general contractor seldom self-performs a substantial portion of the work, and functions instead as more of a construction manager than a GC. To make matters worse, subcontractors are beginning to do the same by hiring their own subs to actually perform the work. With tier upon tier and with responsibility spread around, whom do you deal with when you have a problem on site?

In turn, Allen (1996) describes the impact of increased subcontracting on production control:

> Suddenly there was a contract between the manager and the production process and yet we still acted as if we directly controlled the work face. The contractual problems that inevitably arose required a fix, and we started down the road to managing contractors, not production.

Indeed, at the end of that road, Bennett and Ferry (1990) found a total lack of production control: "...the specialists [contractors] are just thrown together and told to sort things out between themselves".

The impacts on design are interestingly illustrated by Gallo et al. (2002). They note the tendency to select designers on the basis of lowest price. Even if they do not directly connect this to reductions in design fees, such a relationship can be assumed.. Further, they state:

> Key research conclusions based on data collected and analysed are:
>
> - design and documentation quality have worsened over time apparently in direct relationship with reductions in design fees; and
> - at the same time there have been increases in project time, costs and non-desirable elements of construction including inter alia disputation, project delays, and cost overruns.

Similar observations have been done in Japan (Andi & Minato 2003):

> ”...the reduction in the level of design fees together with the limited time made available to carry out the work have caused problems in the quality of design documents. Further, these problems have affected the efficiency of the construction process. [...] By reducing design fees to minimize costs, clients are by their own actions contributing to the problems.”

3.3.2 Making-do as the response in construction

Does the transformation lead to the increase of work-in-progress also in construction? Surely, to some extent. However, there is another response, maybe more important at least in construction: making-do.

Making-do as a waste 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 not only to materials, but to all other inputs such as machinery, tools, personnel, external conditions, instructions etc. Especially in production situations that resemble assembly (i.e. there are several uncertain inflows to the task) making-do is a common phenomenon.

The consequences of the transformation model, insufficient volume of design effort and production control effort, lead naturally to making-do: tasks have to be carried out or at least started in spite of lacking prerequisites.

However, making-do has a price, in the form of reduced productivity and quality, as well as increased accident risk.

3.3.3 Rise and fall of the transformation model: a country study

Is the corrupting impact of the transformation model already over in construction, similarly to construction? Let’s take a look at the situation in Finland. As in other countries, the use of the transformation model was mirrored especially during the 1990’s in the increased use of subcontracting and the trend of selecting also designers based on price. The deep economic recession that started in 1992 was one factor pushing in this direction. In addition, the membership of Finland in the European Union, realized in 1995, meant that the community legislation had to be followed. Thus, the national architectural fee list, established by SAFA, the architects’ association, was abolished as illegal in view of the Directive 92/50/EEC (Exhibit 1).

However, the negative impacts were widely felt and different countermeasures were taken. For example, a large research and development programme PROBUILD on procurement methods was initiated in 1997. A specific Center for Quality in Construction was established. It was even legally stipulated in 1999 that there must be a lead designer in each project. The responsibility of the lead designer is to take care of the design as a totality as well as of the quality of design. The purpose was to ensure better design integration.

However, the tide could not be stemmed. A first weak signal of the more serious trouble to come was in the falling down of a massive steel tank at a paper factory in 1996, leading to one fatality. The Accident Investigation Board was requested to investigate the causes of the accident. The design and execution process was found to be very fragmented, with serious information gaps between the stakeholders, and with opaquely distributed responsibility. Among its recommendations, published in 1998, the Board suggested that the problems caused by splitting of construction projects, by division of responsibility as well as by the extreme pursuit to find the lowest bid should be charted and when necessary action should be taken for remedying the shortcomings.

In Council Directive 92/50/EEC of 18 June 1992, relating to the coordination of procedures for the award of public service contract, Article 36 states as follows: …the criteria on which the contracting authority shall base the award of contracts may be:
(a) where the award is made to the economically most advantageous tender, various criteria relating to the contract: for example, quality, technical merit, aesthetic and functional characteristics, technical assistance and after-sales service, delivery date, delivery period or period of completion, price; or
(b) the lowest price only.

Exhibit 1. EU regulation on awarding public contracts

However, no action followed on the part of authorities or other stakeholders. The turning point in the public awareness was reached only in 2003, when new or relatively new buildings started to collapse. The roofs of several large-span buildings, sports halls, markets and swimming facilities collapsed or were found dangerous during just one year. The leading trade journal for construction titled its editorial: "Sick industry". The President of the architects' association, SAFA, wrote in the leading newspaper (Vahtera 2003):

> What mean the news about collapsing structures? When structures fail, the question is about a problem related to design, affecting the whole construction sector. [...]
> "The most economically advantageous tender" means almost without exceptions the lowest price. [...]
> Buyers' markets compel the bidders of [design] work to a situation, where the only way of getting assignments is to reduce the amount of work done. [...]

It is interesting to note how similar these observations are in comparison to the above presented conclusions from Australian ja Japanese studies.

Even of the immediate causes of these collapses varied, the common underlying cause seems thus to be in the fragmentation caused by dominant thinking, i.e. the use of contractual methods viewed as progressive both nationally and internationally. It is also evident that these collapses, which enjoyed wide publicity, form only the tip of the iceberg of defects and errors. In construction industries of other countries, the impacts of the transformation model seem to have channelled more into costly claims, and a fatal growth of serious errors has been avoided for fear of litigation.

It seems that companies, professional associations and authorities have finally started to take serious countermeasures. Thus, it would seem that at least regarding Finland, the turning point falls, roughly, into around 2005 (Figure 2).

Thus unfortunately, construction management, when carried out in the transformation mode, becomes a mill of self-inflicted problems, due to lacking recognition of uncertainty of and interdependencies between tasks. Ironically, what the development of theory of structural mechanics had achieved – a relatively good level of structural safety – has been undermined by a deficient theory in the realm of construction management, the transformation model of production.

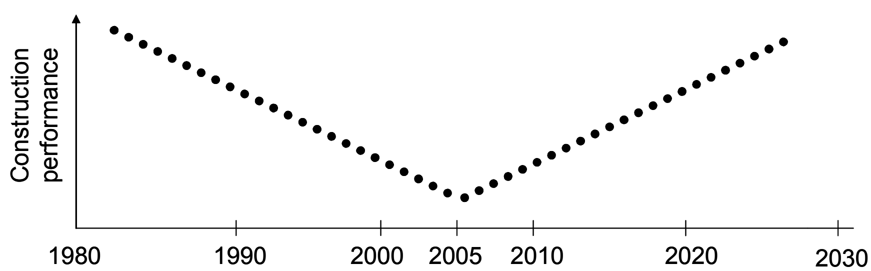

Figure 2. Speculation on the pattern of construction performance in 1980 - 2030.

4. WHAT IS SHOULD BE THE NEW THEORY?

What then would be the wider and more powerful theoretical foundation for project management in construction? Based on analysis of the weaknesses of the present foundation and consideration of competing theories and methods (Koskela & Howell 2002b, Koskela 2003), it is proposed – as a starting point - to include the theories indicated in Table 2 into the new foundation.

Table 2. Ingredients of a new theoretical foundation of project management

<table>
<tr><th colspan="2">Subject of theory</th><th>Relevant theories</th></tr>
<tr><td colspan="2">Project</td><td>Transformation
Flow
Value generation</td></tr>
<tr><td rowspan="3">Management</td><td>Planning</td><td>Management-as-planning
Management-as-organizing</td></tr>
<tr><td>Execution</td><td>Classical communication theory
Language/action perspective</td></tr>
<tr><td>Control</td><td>Thermostat model
Scientific experimentation model</td></tr>
</table>

Regarding the theory of project, the (partial) models of operations as flow and value generation add the consideration of time, variability and customer to the conceptualization provided by the transformation model (Koskela 2000). Similarly, the theoretical foundation of management has to be extended. Regarding planning, the approach of management-as-organizing adds the idea of human activity as inherently situated (Johnston & Brennan 1996). Thus, planning should also focus on structuring the environment to contribute to purposeful acting. Concerning managerial execution, in the language/action perspective, described by Winograd and Flores (1986), action is triggered by explicit commitments (promises) resulting from two-way communication, instead of the mere one-way communication (orders) of the classical communication theory. The scientific experimentation model of control of Shewhart (Shewhart & Deming 1939) focuses on finding causes of deviations and acting on those causes, instead of only changing the performance level for achieving a predetermined goal in case of a deviation. The scientific experimentation model adds thus the aspect of learning to control.

It should be clear that what has been presented does not yet provide a unified and complete theoretical foundation for project management. However, this foundation shows manifestly that a better theoretical foundation can be created for project management.

But how can this foundation be practically applied? An example is provided by Last Planner™ (Ballard & Howell 1998), which is maybe the most central new tool developed specifically for production situation on construction sites.

Last Planner™ has provided a most fruitful object for theoretical interpretation as well as further refining of theories. Last Planner™ integrates the transformation and flow views (Koskela 2000). In the framework of the flow view, Last Planner™ is geared towards reducing variability, and it contributes thus especially to waste minimization. Regarding management theories, Last Planner™ is primarily based on the alternative theories of planning, execution and control, as identified above: managing-as-organizing, language/action perspective, and scientific experimentation model (Koskela & Howell 2002b).

5. CONCLUSIONS

Three issues have been emphasized in this presentation. First, achieving progress in overcoming the malaise of construction: low productivity, poor quality and high accident rate, necessitates an explicit theoretical foundation for construction management. Second, the underlying implicit theory of conventional construction management is simply counterproductive and adds to the problems encountered in construction. Third, an emergent new theoretical foundation can be pinpointed, which explains the shortcomings of the old theory and brings forth practical benefits when industrially applied.

In view of these three issues, let's recollect again the main claims by Loosemore & al. (2003). Instead of being a managerial fad, lean construction represents a solidly grounded academic and industrial movement towards renewing construction management. Instead of fostering superficiality, lean construction is theory-based and theory-seeking. Instead of being dangerous, lean construction is demonstratedly beneficial in several regards. It only remains to be wished that the arguments presented here stimulate Loosemore and his co-authors, at least, to sharpen their critique against lean construction, if not to revise their standpoint.

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