RE-ENGINEERING, CONCURRENT ENGINEERING, LEAN PRODUCTION: WHAT IS THE IDEAL ANTIDOTE FOR THE CONSTRUCTION INDUSTRY'S AILMENTS? OR WHAT IS THE RIGHT QUESTION?

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Abstract
It is widely agreed that the practice of construction is deficient and requires improvement. However, the construction research community has had little to contribute to a solution, except trialling new approaches from general management scene or advancing technological tools. It is argued that a new research frontier is needed, where integral understanding of operations, construction and computing is created. Through this understanding, real progress can be achieved.

Keywords: Lean production, concurrent engineering, re-engineering, operations management, construction engineering and management, construction computing

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INTRODUCTION

Several new approaches are presently being introduced in construction science. Regarding lean production, the International Group for Lean Construction has existed since 1993. Annual conferences[1] are the main activity of this group. The First International Conference on Concurrent Engineering in Construction was held in July 1997 in London. This Conference on Re-engineering in Construction is the first of its kind.

So it is no wonder, if the question of the title comes to mind. Re-engineering, concurrent engineering, lean production: what is the ideal antidote for the construction industry's ailments? However, I think this is a wrong question. Not only simply wrong, but threefoldly wrong. First, these three approaches share a common theoretical basis, and their core contribution is more or less the same. In consequence, it is wrong to oppose them with each other. Secondly, these approaches are generic ones; they in themselves do not add to our understanding specifically of construction and its management. However, exactly the lack of understanding may be the source of many a problem. Thirdly, the important but problematic issue of computing in construction is overseen in this question (even if it could be claimed that re-engineering covers it).

In this paper, these three claims are treated in turn.

UNDERSTANDING OPERATIONS

[1] The papers of the three first conferences are available in (Alarcón 1997).

Operations management: the umbrella

From the point of scientific taxonomy, lean production (LP), concurrent engineering (CE) and re-engineering (RE) are all subsets of the "mother" discipline of operations management (called also, in a somewhat narrower sense, production management; in the beginning of the century, industrial engineering was the corresponding discipline). The concept of operation refers to the fact that it is (mostly physical) operations, rather than strategy, that is addressed. Also that concept is convenient in that it covers both production, service and administrative operations.

During this century, the discipline of operations management and its predecessors has largely subscribed to one overarching conceptual framework: conversion model. The core of the conversion model is in (1) seeing operation (production, design, etc.) as a conversion[2] of inputs into outputs (Grubbström 1995), and (2) in the idea of breaking up the total conversion into smaller, more manageable conversions (analytical reductionism).

However, in the first decades of this century, there were also other conceptual frameworks in industrial engineering. These will be discussed next.

Sources of the "new" ideas

Conceptually, the new approaches (LP, CE, RE) are based on such ideas as elimination of waste; time compression as a means for waste elimination; emphasis on processes rather than on individual activities. Actually, most of these underpinnings were discussed in classical industrial engineering.

The concept of waste was widely used already in the twenties, and the relation between time compression and waste was well known. In the Report on Elimination of Waste in Industry, the following is stated (Anon. 1921):

> Conscious production control tends to reduce or eliminate waste by shortening the total time of production.

It was recommended that processes should be addressed first, before individual activities; today we would call this as process-orientation (Clark 1922):

> The part of the work of management described above, that is, keeping work moving through the plant at a rapid pace, should be well organized before very much time is devoted to individual production, because the delays under the control of management are usually much greater in extent than those under the control of individual workmen, and because improvements in the management will have an appreciable effect on the output of the workmen.

The rationale of process redesign and improvement was formulated by Frank and Lilian Gilbreth (1922) in a paper advocating process modeling as follows:

> Every detail of a process is more or less affected by every other detail; therefore the entire process must be presented in such a form that it can be visualized all at once before any changes are made in any of its subdivisions.

The Gilbreths refer to improvements that presently would be obviously called re-engineering:

> In many instances recording industrial processes in process-chart form has resulted in astonishing improvements.

However, for reasons unknown to me, these ideas fell into disgrace and were taken seriously[3] and re-adopted only decades later, first by industrial engineers at Toyota, and

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[2] The term transformation is also often used.

[3] Shingo (1988) explicitly refers to the above quoted paper of the Gilbreths as the stimulus to his JIT theory.

then, under the title of JIT, by other manufacturing communities. Thus JIT and all later associated approaches make up a continuation of the research agenda and the tradition of industrial engineering of the beginning of this century.

Diffusion

The application of these "new" ideas from industrial engineering has diffused from production (lean production) to engineering design (concurrent engineering) and general business administration (process re-engineering). Because it is called differently in these three application areas, let us summarize these:

Lean production. Lean production refers to a new set of conceptualization, principles, methods and tools of production, comprehensively documented by Womack and Jones (1990, 1996). The objective in lean production is to decrease the inherent waste in production, in contrast to the conventional approach of replacement of human labour through technology. The roots of lean production are in the evolution of JIT techniques at Toyota and related theoretical work (Shingo 1988). In West, lean production has mainly diffused as engineering based approach without major research contribution.

Concurrent engineering. Concurrent engineering has been defined as a design process where all life cycle phases of a product are considered simultaneously from the conceptual stage through the detailed design stage (Kusiak 1993). Like lean production, concurrent engineering has originated in Japan and diffused through professional circles. But in contradiction to lean production, it has evolved solely through engineering practice, rather than based on new theoretical insights (Sobek & Ward 1996). Thus, it is no wonder that there is confusion about the definition and underlying theory of concurrent engineering. Thus, in a recent overview on concurrent engineering (Prasad 1996), not less than eight common definitions of concurrent engineering are listed. However, it can be shown that concurrent engineering is based on the same conceptualizations as lean production (Koskela & Huovila 1997).

Process re-engineering. This approach, which recently has rapidly diffused in the areas of business management, service industries and public administration, stresses a radical reconfiguration of work processes and tasks, especially with respect to information technology as an enabler (Davenport 1993, Hammer 1990). Conceptually and theoretically, its roots are in industrial engineering, especially in JIT and quality approaches.[4] Like its fellow approaches, it has diffused through professional and consultant circles. The major research contribution of re-engineering is the simultaneous consideration of computer and non-computer means for process redesign.

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[4] Actually, in an early contribution, Davenport and Short (1990) suggest to call the emergent new approach as new industrial engineering. However, the term re-engineering became established.

What is common?

Lean production, concurrent engineering and re-engineering have two common features; (1) they subscribe to the same theoretical foundation, (2) this theoretical foundation is not explicit nor mature (argued in more detail in Koskela (1996)).

Indeed, the common feature of lean production, concurrent engineering and re-engineering is that they all strive to address the deficiencies of the conversion model through richer conceptual foundations. By means of the concept of flow, such important features as time, space and uncertainty, abstracted away in the conversion model, are addressed. By means of the conceptual scheme of a supplier-customer pair, the interdependencies in the flows are covered.

However, both these three approaches and the mother discipline of operations management are startlingly unaware[5] of their conceptual foundations. It is also understandable, that these foundations, when not explicit, have not developed further towards sharper concepts and formalization.

Thus, the theoretical and conceptual foundation of operations management needs to be made solid and explicit. Until this happens, we are in the difficult and confusing situation that even the most fundamental concepts, like operation, process and value, are generally used in several, sometimes diametrically opposed meanings.

What is the ideal antidote?

Thus, lean production, concurrent engineering and re-engineering are not alternatives, but titles for specific knowledge regarding the application of up-to-date operations management principles in different types of operations. All are needed in construction.

UNDERSTANDING CONSTRUCTION

However, the adoption of better generic operations management concepts in construction is not enough. There is a need to understand, which kind of operations make up construction. This is illustrated in Table 1.

Table 1. The different levels of knowledge in regard to operations.

Conceptualization of operations; related universal laws and principles
Taxonomy of operations
Design, control and improvement principles for different types of operations

Do we understand the specificities (or peculiarities) of construction? No. There is very little direct research into this issue, one notable exception being Nam and Tatum (1988). It is true, that in many studies the specific features of construction are commented, but there is little cumulation of knowledge in this regard.

This lack of construction related theories has not gone unobserved by researchers. The lack of sufficient conceptual framework for construction project organizational design has been discussed by Sanvido (1988). Laufer and Tucker (1987) suggest an overall re-examination of the philosophy of project management. Halpin (1994) claims that "we have not gone far enough in seeking a basic framework for the construction of facilities".

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5 For example, the recommendable new textbook on operations management (Slack & al. 1995) still subscribes to the view of operation as a transformation. The same is the situation in other textbooks studied.

What impacts has this lack of construction theories? Shortly, we have been without filter and focus. Firstly, a construction theory would provide a filter, by means of which it is possible to consider the applicability of methods and techniques, originated in other contexts, in construction. Lacking such a filter, we often have heroically tried to adopt and adapt such technologies that just do not or only poorly match with construction reality.

A classic example is provided by the Critical Path Method (CPM). The shortcomings of the CPM from construction point of view have since long been pointed out: it does not support the analysis of spatial work flows on site, as critics have since long argued (Peer 1974, Birrell 1980). Not until the 90'ies has research started to address this issue; in fact, Russell and Wong (1993) show that it is possible to define a generalized method that overcomes this problem.

Secondly, our research has lacked a sharp focus. There has not been any concentrated effort (research frontier) to address the issues and problems specific to construction, which obviously will not be alleviated by just waiting for new methods from outside. Such specific issues include, for instance, one-of-a-kind production, site production and temporary organization.

Here production control in site production provides for an example. As Ballard and Howell (1997) argue, construction can be said to have not had a theory of production control proper, that would take into consideration the high degree of uncertainty of construction operations.

To sum up: in our eagerness to welcome external concepts and methods, we have turned our back to construction, and largely failed to cultivate and accumulate knowledge about our subject proper. The theory of construction invites for research.

UNDERSTANDING COMPUTING

Unavoidably, we have to extend our discussion to computing when considering improvement of construction. At the risk of oversimplification, I would argue that the underlying conceptual framework (or mental model) of construction computing has been like in Figure 1: Computing (information technology implementation) leads directly to benefits and improvement of construction. This corresponds to the general approach to the use of information technology, largely prevalent still in the beginning of the 1990's (Davenport 1993). Due to its excessive focus on technology, rather than the context of its application, this view has developed to a bottleneck in itself (Davenport 1994).

However, associated with this framework when used in construction, there often are three additional, implicit ideas that require critical evaluation:

- Computing provides the primary tool for solving problems in construction.
- Computing provides the (or a) theory for understanding construction.
- Construction computing is intrinsically valuable.

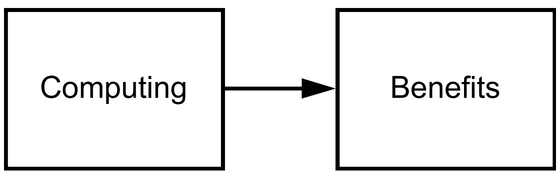

Figure 1. Underlying conceptual framework of construction computing (inspired by Davenport (1993)).

These underlying ideas (space does not allow here to justify their existence) may cause the following problems, discussed recently by construction observers:

- Other, non-computer means for improving processes in construction are not addressed properly, neither in research nor in practice.
- The development of construction theories is practically neglected.
- The selection of research themes does not necessarily serve the needs and opportunities of construction process improvement.

On the generic level of information technology use in management, this model (Fig. 1) is being rejected, thanks to re-engineering. In re-engineering, it is acknowledged that information technology applications do not directly contribute to benefits, but through the intermediation of information processes (Figure 2). Information processes may restrain or amplify the effect of information technology. In re-engineering, the interest is especially focused on the cases where information technology enables a new, widely superior process design.

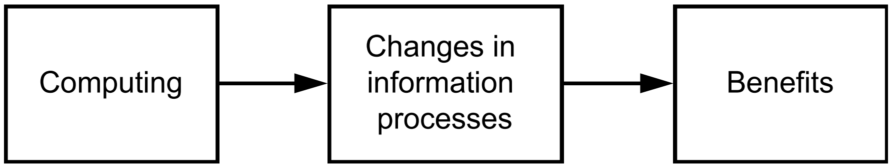

Figure 2. Underlying framework of re-engineering (Davenport 1993).

The interest in re-engineering has rapidly increased in construction research and practice (Betts & Wood-Harper 1994, Ibbs 1994). Indeed, re-engineering has to some extent pointed out the way towards more effective approach to information technology. However, one cannot be fully satisfied with re-engineering as a foundation: it lacks an explicit theory and it takes into consideration only a part of all process improvement/redesign principles and methods.

However, in this regard, interesting direction is given by Fenves (1996) in his recent, noteworthy paper. He calls for a science base of application of information technologies in civil and structural engineering. One component of this science base would deal with the understanding of the processes of planning, design, management, etc. that engineers use:

> ...we need to agree on an intellectual framework, in order to create a scientific understanding or abstraction of engineering processes in practice.

This can be interpreted as follows: The bottleneck in construction computing is not in deficient capabilities of information technology in general or its specific applications, but in deficient understanding of construction. - Also Björk (1997) discusses the need for such a framework.

Thus, what Fenves wants to add to computing research, is understanding related to operations in general and understanding of construction specifically; that is, the previous themes in this paper. Thus, I propose to structure this issue as illustrated in Figure 3. Here it is explicitly acknowledged, that

- all three factors (generic operations management principles, understanding of construction peculiarities, and computing) approaches may bring about changes in information and material processes, and
- these approaches interact with each other.

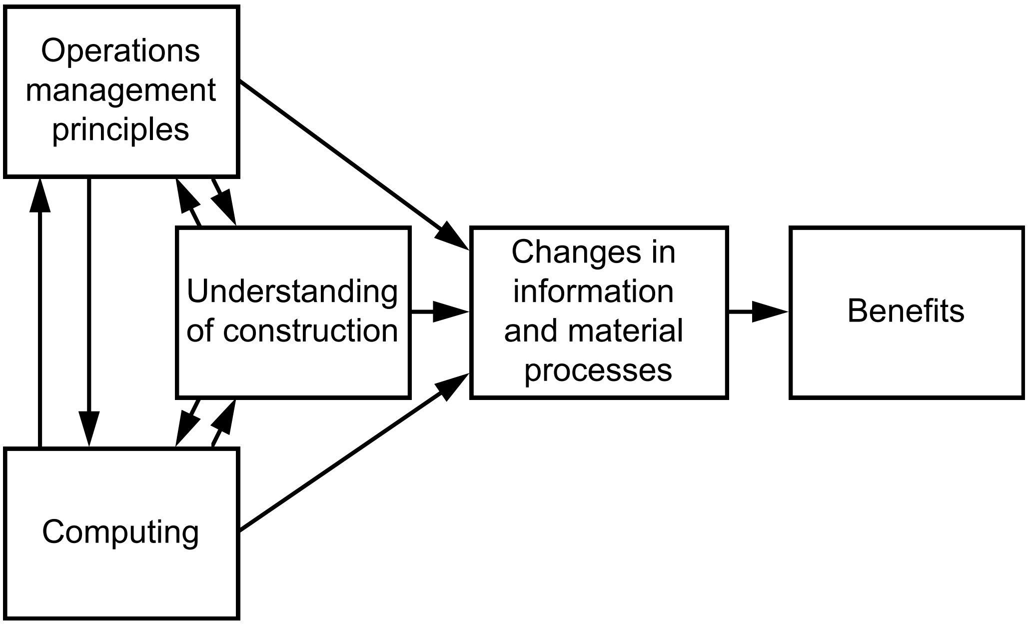

Figure 3. The interrelations between operations management, construction (science) and computing.

The way changes and benefits emerge in construction is dependent on the fit between interventions emanating from these three fields. Let us take an example. The transparency of the operational situation is one important principle (originating from lean production) of modern operations management. However, due to construction peculiarities, especially site production of a one-of-a-kind product, it is difficult to implement this principle in practice. But here would computing be very helpful, along with all present possibilities of simulation and visualization. Thus, computer aided transparency is suggested as one part of the implementation of operations management principles. On the other hand, simulation and visualization, when implemented in isolation, have not, to my knowledge, provided any solution because conventional construction management does not stress transparency, and can thus not benefit from it.

Thus, understanding and utilization of the interactions among these three fields are most important.

CONCLUSIONS

Assume, for a moment, that we could simultaneously observe all the world's construction projects. Over and over, the same scenes would repeat: cost and time overruns are generated; defective building parts are redone or remain as latent defects; construction workers die or are injured in accidents. Why it is so? Can something be done?

Obviously, things could be much better. However, the precondition is that the scientific community focusing on construction takes its job self-confidently and seriously, and creates a science base and a research frontier to support the practical improvement. Integral understanding of operations, construction and computing is needed. Through this understanding, real progress can be achieved.

The ingredients are there, the recipe is there. I think that this is the beginning of a genuine science of construction. That implies that we, as researchers, are on the threshold of a very challenging, fascinating and significant time.

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