Is structural change the primary solution to the problems of construction?

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Is structural change the primary solution to the problems of construction?

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What is the cause for the well-known problems of construction? What should be done to achieve a solution to these problems? A number of renewal initiatives, such as industrialization, open building, design/build, partnering, re-engineering and others, have been put forward. A common feature of such initiatives is that they imply structural changes to the organizational pattern and/or to the flows of information and materials. The aim here is to discuss critically the idea of the primacy of the structural solution for the problems of construction. To create a basis for such discussion, the theoretical field related to construction is outlined. Three major theoretical areas are recognized: theory of production, theory of management and conceptualization of the peculiarities of construction. For the theory of production, there are three conceptualizations that should be used simultaneously: transformation, flow and value generation (the TFV framework). For the theory of management, there are three intrinsically different managerial actions: design, operation and improvement of a production system. For the peculiarities, three major factors are perceived: one-of-a-kind nature of projects, site production and temporary organization. Based on this framework, a number of conclusions are drawn. Foremost is that due to its peculiarities, construction is characterized by a high level of variability, and the role of managerial action at the level of operation and improvement is crucial in stemming the penalties and further propagation of variability. Five renewal initiatives are analysed based on the theoretical framework. They all focus primarily on production system change and all have given modest or disappointing results. Even if the causal relation cannot be established definitively, there is evidence for the claim that it is the neglect of changes at the level of operation and improvement that has contributed to the relative lack of results. As a conclusion, it is argued that the problems of construction require (besides structural changes in the production system) new initiatives at the level of operation and improvement. Moreover, it is concluded that to support integrative new solutions to the pervasive practical problems of construction, we need to develop further the theoretical foundation, or first principles, of production in general and especially in construction.

Keywords: construction, construction performance, production theory, re-engineering construction, structural change
Introduction

What is the cause for the well-known problems of construction? What should be done to achieve a solution to these problems? Answers to the questions have been sought since the early 20th century. However, we still do not have such commonly accepted and practically proven answers that could be used in the renewal of this industry.

The author has elsewhere (Koskela, 2000; Koskela and Vrijhoef, 2001) put forward the thesis that to answer these practical questions adequately, the theoretical foundation of production in general and especially of construction needs examination. This is also the underlying theme of the present paper, the thrust of which is, however, a critical analysis of a number of current recipes for the renewal of construction.

A recurrent feature in many initiatives for a construction renewal is that a new production system design (e.g. a structural change in the way projects are delivered) would provide the resolution. Historically, industrialization of construction might have been the first approach for a new system design. A number of new organizational models for construction project delivery, such as open building and the sequential process, subscribe to this idea. According to the re-engineering movement, the solution is in the redesign of processes (Hammer and Champy, 1993). Another popular view suggests that an integrated design-build contract is superior to the conventional, separated design–bid–build procurement (Bennett et al., 1997). A further view is that advancing partnering is a solution to the problems of construction (Baden Hellard, 1995).

While the approaches to renewal mentioned above have their origin primarily in industrial and professional circles, the idea of the primacy of the structural solutions has found support also in academic circles. Cox and Townsend (1998) found that there were clear and unambiguous structural reasons why significant construction performance improvements had been possible in a number of pioneering companies. Garnett et al. (1998) suggested the development of lean thinking from a strategic viewpoint. In practical terms, this refers to reorganizing around core business processes.

The aim of the present paper is to discuss critically the idea of the primacy of a structural solution for the problems of construction. Its content is as follows. The theoretical field related to construction management is first outlined. The major proposals for the renewal of construction are then critically reviewed. Finally, conclusions are drawn from the arguments and evidence presented.

Theoretical field

It is argued that the theoretical field related to construction divides into three main parts: theory of production, theory of management (of production) and conceptualization of peculiarities of construction as a special type of production.

Production dimension: transformation, flow, value generation

Historical analysis reveals that three different conceptualizations of production have been used in practice as well as conceptually advanced in the 20th century (Koskela, 2000). In the first, production is viewed as a transformation of inputs to outputs. Production management equates to disaggregating the total transformation into elementary transformations or tasks and carrying out the tasks as efficiently as possible. The work of Wortmann et al. (1997) exemplifies this approach. The transformation concept of production has been the dominant underpinning of production and operations management, especially in the latter 20th century. In addition, the fields of construction management and project management have subscribed to this conceptualization. The second conceptualization views production as a flow, where in addition to transformation there are waiting, inspection and moving stages. Production management equates to minimizing the share of non-transformation stages of the production flow, especially by reducing variability. Hopp and Spearman (1996) represent this approach. The third conceptualization views production as a means for the fulfillment of customer needs. Production management equates to translating these needs accurately into a design solution and then producing products that conform to the specified design. Thus, the target is to avoid value loss. Cook (1997) provides an example of this conceptualization.

Each of the three concepts has been the dominant idea of a major production template. The transformation concept was...
the mainstream industrial template of the 20th century; the flow concept was used for lean production; and the value generation concept was used for Total Quality Management (TQM) and customer-oriented manufacturing. Each template has brought about performance gains in comparison with its predecessor.

It is argued that all these conceptualizations are necessary and should be used simultaneously. The resulting transformation–flow–value generation model of production is called the TFV theory of production. Correspondingly, its elements are called the T, F and V view on production.

Management dimension: structure, operation, improvement

Management of production may be divided into three constituent parts:

- Design\(^5\) of the production system
- Operation\(^6\) of the production system in order to get the intended production realized. (Operation may be further divided into planning, controlling and correcting)
- Improvement of the production system

This view has been established in operations management long since. For example, in the first edition of Buffa’s (1961) well-known textbook on production management, one part (of four in total) was devoted to ‘Design of Production System’ and one to ‘Operation and Control of Production Systems’. In the latter, there is a chapter with the title ‘Control and Improvement of Production Costs’, where improvement is mentioned briefly. The recent textbook by Slack et al. (1995) contains one part each for, respectively, design, planning and control, and improvement.

The significance of this conceptualization of management can be justified by considering the major goal of the flow view of production, reduction of non-value-adding activities (waste). Why are there non-value-adding activities in the first place?

There seem to be three root causes: the structure of production system, the way production is controlled and the inherent nature of production:

- The structure of the production system determines the physical flow that is traversed by material and information. Thus, for example, the layout of a factory dictates the amount of waste associated with moving material from one workstation to the next.
- The way production is controlled affects waste in at least two ways. First, the control principles used may produce more or less waste. Second, deficiencies in conforming to the intended principles may cause waste.
- It is in the nature of production that waste exists: defects emerge, machines break down, accidents happen. Especially, variability of all productive activities seems to be an inherent feature, as well as human error. Characteristically, this variability is statistical by nature, and often it can be assessed only by monitoring the production system long enough.

Thus, these three root causes of waste differ regarding their time frame. The waste associated with the structure is determined at the time of the design of the system, and is thus tackled in advance. The waste associated with control is tackled during the production. The waste associated with the inherent nature of production is dealt with after the production. Evidently, this means that the methods of attacking these three sources of waste are also different. This is the rationale behind distinguishing the three aspects of production management: design, operation and improvement of production.

Peculiarities – why is construction different?

An overview on construction peculiarities, as presented in prior literature, is presented in Table 1. One of the first to discuss the peculiarities of construction might have been Turin (Groa´k, 1992). He took the view that advances in construction are often related to the elimination of certain peculiarities. Nam and Tatum (1988) come to a similar conclusion in their analysis of the impact of peculiarities on construction innovation. Warszawski (1990) compares construction with manufacturing and argues that for the sake of efficiency, industrialized construction should be set as a target. Carassus (1998) takes the view that one fundamental specificity, namely that constructed products are located on a site, structures most of the other specific characteristics, as presented by him.

Even if it is easy to find treatments of construction peculiarities, there is little accumulation in understanding in this respect. This is illustrated by the fact that there is no cross-referencing among the sources discussed here. Moreover, related knowledge is qualitative; there have been few, if any, attempts to acquire quantitative data on the occurrence or impact of these peculiarities.

From the point of view of production/operations management, it is convenient to group the significant peculiarities of construction, as presented above, into three major categories\(^7\): one-of-a-kind nature of projects, site production and temporary organization.

One-of-a-kind production is not a unique feature of construction. Even if manufacturing is largely understood as mass production, a major share of manufacturing output consists actually of one-of-a-kind products, mostly in the capital goods sector (hence the term ‘project industries’).

The one-of-a-kind nature of construction output is caused by differing needs and priorities of the client, by differing sites and surroundings, and by differing views of designers on the best design solutions (Warszawski, 1990). This one-of-a-kind nature, which varies along a continuum, most often covers the overall form of the building or facility, and the interfaces
between different subsystems. The materials, components and skills needed are usually the same or similar. From the point of view of contractors and design offices, there is often continuity and repetition: roughly similar projects and tasks recur. Thus, it has to be stressed that the problems associated with one-of-a-kindness affect only certain aspects in any project. In comparison with many other industries, like software programming, the degree of one-of-a-kindness in construction is not extreme.

One-of-a-kind production is characterized by two issues (Riis et al., 1992; Wortmann, 1992). First, product design is an integral part of production (i.e. product design or development beyond mere selection of options or configuration design). Second, there is uncertainty, which is critical especially with regard to customer order acceptance.

Construction production is typically carried out at the final site of the product to be constructed. Thus, construction is characterized by site production, a feature shared by only a few other industries, like mining and agriculture. In construction, the concept of site production refers actually to a bundle of features:

- Site as a resource: the site is a necessary input resource for production
- Lack of shelter: there is usually little protection against elements or intrusion, rendering operations prone to interruptions
- Local resources and conditions: local material and labour input often have to be used, potentially adding to uncertainty; other areas of uncertainty include site geology and other environmental factors
- Creating the production infrastructure: the production infrastructure (machines, manpower, etc.) has to be planned, procured and set up on site
- Space needed by production (workstations are mobile in relation to the product): the spatial flow of workstations (teams) has to be coordinated (in contrast to a factory, where only material flow through workstations is planned)

It is evident these characteristics of site production add to uncertainty and complexity of construction in comparison with stationary production.

A construction project organization is usually a temporary organization designed and assembled for the purpose of the particular project. It is made up of different companies and design practices which have not necessarily worked together before and which are tied to the project by means of varying contractual arrangements. The temporary nature of the organization extends to the workforce, which may be employed for a particular project rather than permanently. This feature reflects the one-of-a-kind nature of a constructed product: several alternative materials may be used, each requiring specialist expertise in design and installation. On the other hand, as mentioned above, the economic necessity of using local labour or subcontractors is one cause of temporary organization.

Of course, temporary organization is not unusual; it is being advanced as a future production mode in the framework of agile manufacturing and virtual production.

Table 1 Views on peculiarities of constructed products and construction

<table>
<thead>
<tr>
<th>Source</th>
<th>Peculiarities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turin (from Groä‡k 1992)</td>
<td>Fixity, Uniqueness, Weight, Complexity of organization and manufacture, Long production time, High initial and running costs, Longevity in use, Often sold before built</td>
</tr>
<tr>
<td>Nam and Tatum (1988)</td>
<td>Immobility, Complexity, Durability, Costliness, High level of social responsibility</td>
</tr>
<tr>
<td>Warszawski (1990)</td>
<td>Work dispersed among many temporary locations, Long service life of a typical project, Small extent of standardization, each project has distinctive features, Large number of tasks requiring a high degree of manual skills necessary to complete a typical construction product, Each task is performed over large work area with workers moving from one place to another, Rugged and harsh work environment, High turnover of workers, Authority divided between sponsor, designers, local government, contractor and subcontractors</td>
</tr>
<tr>
<td>Carassus (1998)</td>
<td>Located on a site, Localized orders of extraordinary diversity, Production of prototypes, Artistic creation, A producer not controlling the overall process, Itinerant, short-lived, complex and random site work, Localized products that can be durably adapted and modernized, Rules and conventions playing a considerable role</td>
</tr>
</tbody>
</table>
Implications of peculiarities

What are the implications of the peculiarities of construction for the management of construction from the viewpoint of the three production concepts? This is a wide and largely uncharted research area. By way of example, the implications for the flow concept can be summarized. Analysis (Koskela, 2000) shows that the peculiarities of construction have a large impact on the structure and behaviour of material flows:

- There are three flow types (material flow, location flow and assembly flow) in action on site in contrast to two types in a typical factory (material flow, assembly flow)
- There is a high degree of inherent variability due to construction peculiarities associated with these flows
- Production in construction is of assembly type, which is inherently vulnerable to (input) flow variability
- Construction is, by nature, a prototype production normally carried out for debugging errors in designs or production plans
- Unlike the situation in a factory, a part can be simultaneously at several workstations, leading to work in sub-optimal conditions: this is a waste type characteristic of construction

What should be done at the different managerial levels in view of these implications? First, it has to be stressed that the level of variability is high and the production situation is vulnerable to variability. Thus, the role of operation and improvement accentuate. Production should be controlled so that variability and its propagation are cut back and the disadvantages of penalties of variability are minimized. Also, the production system and its operation should be improved; in particular, variability should be reduced. Second, as the high level of variability is caused by the peculiarities, a (seemingly) attractive alternative can be discerned: the production system is designed so that peculiarities and problems due to them are eliminated.

Initial evidence

The theoretical analyses presented can be condensed into three basic propositions (Koskela, 2000):

- Methods founded on the TFV concept are necessary for efficient management of construction
- It is necessary that the TFV principles of production are implemented in the design, operation and improvement of the production system
- Construction peculiarities contribute to waste and value loss. It is necessary to eliminate or reduce those peculiarities and/or to mitigate their impacts at the level of operation and improvement

Theoretical proposition to construction, as it has been presented here, has not been implemented in construction. However, there are a small number of instances where some core parts of it have initially been implemented. Such implementation cases have been analysed in more detail (Koskela, 2000) for creating initial empirical evidence for the propositions presented. The basic criterion for the selection of implementation cases was that principles related to the F and V concepts of production have been implemented. It is justified to assume that in each case principles related to the T concept have been followed before, and thus actually it is a question of augmenting the T principles with F and/or V principles.

Consideration of the implementation cases of TFV principles of production gave support to the basic propositions. The following conclusions were reached.

- First, it is justified to state that the principles based on the TFV concept are also effective in construction. Major improvements can be created immediately by the basic implementation of some F and V principles, which reflects the high levels of waste and value loss
- Second, the comprehensiveness of the implementation of TFV principles of production is a crucial factor. Partial approaches, like those addressing solely system design, have produced only limited results. Rather, evidence suggests implementing this method at the level of both design, operation and improvement of the production system
- Third, the treatment of construction peculiarities seems to be a critical issue requiring further clarification and differentiating construction from other types of production from the point of view of operations management. Indeed, a specific theory of construction should address, among other issues, how to cope with these peculiarities. Based on evidence at hand, it is necessary to eliminate or reduce peculiarities by design and/or to mitigate their impacts at the level of operation and improvement. It seems it is seldom possible to eliminate a peculiarity totally.

Analysis of renewal approaches suggested for construction

This section applies the theoretical base developed for analysing approaches suggested for the renewal of construction. The analysis follows a standard pattern. First, the origin and basics of the approach are described. Then, the performance of the approach is assessed, either regarding the diffusion of the approach (reflecting its performance) or regarding performance directly, if such data are available. Finally, a theoretical explanation for the approach and its performance is given.
The common denominator for the approaches to be analysed is that they are oriented to structural solutions (i.e. production system level). However, they cover the major part of the currently popular renewal recipes. One approach, re-engineering, is generic, while the others have their origin mostly in construction. One important approach that lies outside this category of a structural solution is information technology (IT); the disappointingly modest performance impact of IT in construction has been analysed in Koskela and Kazi (2003).

**Industrialization**

**Approach**

Under the influence of the widely reported success of mass production of cars, the idea of industrialized construction caught the attention of public and construction professionals alike in the early 20th century. Already in the 1930s, Gunnison organized a house factory with a moving belt in the USA. However, 'Fordized, mass-produced housing never caught on' (Hounshell, 1984).

Since the Second World War, the idea of industrialization has received much attention both in Europe and North America, and elsewhere. The intended benefits of industrialization of construction (Warszawski, 1990) include the following: a saving in manual labour on site, a faster construction process and a higher quality of components.

**Performance**

However, in spite of a great number of attempts, there has been a relative lack of success of industrialized building methods (Warszawski, 1990). The share of prefabricated components has gradually risen, but a breakthrough for industrialized construction has still not occurred. Nevertheless, there are some examples of advanced industrialization of construction, notably the Japanese house producers (Gann, 1996) and the American metal-building providers (Ellifritt and LaBoube, 1993).

**Explanation**

Industrialization can be seen as a structural means for eliminating, or at least drastically reducing, on-site activities in construction.

According to Warszawski (1990), the main problem of prefabrication today is the lack of a system approach to its employment on the part of the various parties involved. However, it can be argued that an even greater cause for the lack of success of industrialization has been the lack of consideration of industrialization from the point of view of the F (and V) concept. It is not enough to change construction to a manufacturing process. Even in conventionally managed manufacturing there is much waste and value loss. Another significant point is that when analysed as flow processes, industrialized construction shows widely different characteristics in comparison with site construction.

First, the flow is longer (both in the sense of containing more steps and in the sense of distance) due to two (or even more) production locations: factory and site. This, of course, means that the total variability is greater than in a shorter flow with similar elements. The requirements for cooperation and coordination within the design, planning and installation processes are higher.

Second, the amount of design required is larger (Paus, 1996) and it has to be done earlier than design for on-site construction due to prefabrication lead times (CIRIA, 1999). This is in contrast to the typically tardy determination of stable design solutions in construction design. In practice, this leads to the phenomenon of incomplete and changing orders.

Third, the error correction cycle is longer. For example, dimensional errors of prefabricated components are detected only on site, while for in-situ construction dimensional errors in drawings are often detected in production preparation and can be rectified without large costs (Paus, 1996).

Fourth, requirements for dimensional accuracy are usually higher (in on-site construction activities, it is usually possible to compensate for dimensional variations between adjacent components through sizing of the later components).

This requirement causes problems especially when prefabricated components are assembled beside in-situ constructed parts of the building – this is always the case when installing components adjacent to the foundation, but this situation also often occurs elsewhere.

Thus, the total process of industrialized construction tends to become more complex and vulnerable in comparison with site construction. Consequently, it seems plausible that in badly controlled (or poorly improved) design, prefabrication and site processes of industrialized construction, the increase of costs due to non-value-adding activities has often consumed the theoretical benefits to be gained from industrialization. This, in turn, along with other factors, has presumably led to the relative lack of success of industrialized building methods.

The lesson learned is that the elimination of a construction peculiarity has a price. The characteristics of the production system may change causing new problems to emerge, even if the problems related to the peculiarity are alleviated or eliminated. If the new problems are not tackled adequately, the intended benefits of the elimination of the peculiarity will not be realized.

**Comprehensive organizational renewal**

**Approach**

The traditional way of organizing construction has been found in many countries to hamper performance improvement and innovation. An interesting group of initiatives has resulted from attempts to create a fundamentally new organization for construction, like the ‘sequential procedure’ in France, ‘open building’ in the Netherlands or the ‘new building mode’ in Finland (Lahdenperä, 1995).
The main idea of the sequential procedure (Bobroff and Campagnac, 1987; Cazabat and Melchior, 1988; Lenne et al., 1990; Gibert, 1991) is to plan the site work as successive realizations of autonomous sequences. A sequence is defined in terms of regrouping of tasks by functions of the building, not in terms of traditional techniques or crafts. During a sequence, a firm can operate without interference because it is the only organization on site. After each sequence, there is a quality inspection and change over to the next sequence. The due dates of sequences are strictly controlled.

The open building system is an integrated set of rules and agreements concerning the organization of design and building (van der Werf, 1990; van Randen, 1990; Louwe and van Eck, 1991; Kendall and Teicher, 2000). The distinguishing characteristic is the separation of the ‘support’ (structural) and ‘infill’ (interior work) parts of buildings. The idea is to separate the long-term decisions on the structure of the building from the shorter-term decisions of tenants about the interior of the building.

The goal of the new building mode is to remove the causes of the current inherent problems in construction (Lahdenperä and Pajakkala, 1992; Lahdenperä, 1995). It combines performance-based design and final product (rather than input resource) oriented construction procurement. On the basis of performance requirements, supplier firms (or company groups) offer their pre-engineered (and often prefabricated) solutions for different subassemblies of the building. A detailed procedure for implementing building projects by means of the new model has been prepared. This model was developed toward the end of 1980s.

**Performance**

The sequential procedure has been tried out in a large number of projects, and the method has been further refined. However, Chemiller (1993) comments that the method has not had the development it merits. The open-building system, having been developed over 30 years, is now being introduced by a number of experimental projects in the Netherlands, Japan and other countries. The new construction mode has been experimentally applied to the supply of subassemblies to buildings and also to a few whole buildings. To summarize, all these models have had a somewhat sluggish diffusion.

**Explanation**

It is striking that these initiatives try to avoid or alleviate the problems caused by the peculiarities of construction (Koskela, 1992):

- One-of-a-kind features are reduced through standardization, modular coordination and widened role of contractors and suppliers

- Difficulties of site production are alleviated through increased prefabrication, temporal decoupling, and specialized or multifunctional teams

- Number of temporary linkages between organizations are reduced through encouragement of longer-term strategic alliances

However, elimination of construction peculiarities just brings construction to the same starting point as manufacturing. Unfortunately, a large amount of waste also exists in manufacturing before efforts to address it explicitly begin (through methods based on the F and V concept, like lean production or quality management).

It must be stated that these models indeed have some ambitions towards using the F and V views. For example, the sequential procedure follows closely, even if implicitly, the suggestions of the F concept. The methods and purposes of the sequential procedure can be interpreted from the point of view of F concept principles as follows:

- Waste reduction: the goal is to reduce non value-added time due to excessive specialization. However, other waste components are not so explicitly attacked

- Variability reduction: with several strict due dates and quality control points during the project, defects and problems, causing variability, do not easily migrate downstream. Preplanning is facilitated through reduced external uncertainty

- Cycle time compression: sequence cycle times (site time of each sequence) are compressed by using better preplanning as well as more prefabrication and pre-assembly. (Of course, the total cycle time may be longer than in conventional construction due to preparation and prefabrication)

- Simplification: by establishing strictly sequential work packages, activity interdependencies are reduced and organization and planning of construction is thus simplified

Unfortunately, the models analysed implement the F and V concepts only in a partial way and they do not contain articulated prescriptions for the levels of operation and improvement. Presumably, this has been their major drawback.

**Design–build (DB)**

**Approach**

Since the seminal studies by Bowley (1966), the separation of design and building has been presented as the root problem of construction. Thus, it is no wonder that great expectations have been attached to DB procurement of construction projects, where these two stages are organizationally integrated from the outset. In this case, the client gives a single contract for the execution of both design and construction to one company (usually a contractor). The company has the freedom to
integrate design and construction in a suitable way. This contrasts with the traditional design–bid–build (DBB) procedure.

**Performance**
The performance of the DB delivery system in comparison with other major delivery systems has been studied by Konchar and Sanvido (1998) and Bennett et al. (1996). The results indicate that, statistically, DB outperforms the traditional (DBB) process in several respects; however, the differences are not great. Both studies conclude, based on statistical analyses, that the construction speed of DB is 12% faster than the speed of DBB, and the total delivery speed is 30–33% faster. In the UK, the share of projects ending up above budget by more than 5% was 21% in DB projects in contrast to 32% in DBB projects. In the USA, the corresponding figures were 38 and 51%.

The diffusion of DB has been relatively rapid. Several variants have evolved (Lahdenperä, 2001).

**Explanation**
In critical analysis, it has to be stated that the performance differences found are small and often explainable through factors attributable directly to the structural features of DB rather than to wider efficiency impacts. The construction time is faster because the contractor has a greater possibility to ensure buildability and there is more time for production planning. The total delivery speed of DB is naturally faster for three reasons: the bidding period does not prolong delivery; it is relatively easy to overlap design and construction; and the construction period may be somewhat shorter, for reasons discussed above. On the other hand, the increase of cost and schedule certainty is minor when changing from DBB to DB delivery.

Thus, these studies show statistically that through DB, definite but minor improvements have been reached. The potential of amelioration by only making changes in system design, as implied by DB, is limited. This is also confirmed in practical observations. Barber et al. (1998) observed that operational relationships on projects using new forms of procurement, like design–build–finance–operate (DBFO) or DB act against the strategic aims of the project. Despite working in a seemingly integrated relationship, the actual practices are conventional and fragmented.

**Partnering**

**Approach**
Partnering (Baden Hellard, 1995; Godfrey, 1996; Barlow et al., 1997) dates from the mid-1980s, especially in the USA and UK. Essentially, partnering has been used as a generic term embracing a range of practices designed to promote greater cooperation (Barlow et al., 1997). Achievement of trust and cooperation are essential goals of partnering (McGeorge and Palmer, 1997). The call for teaming, as presented in the Latham Report (Latham, 1994), belongs to this category. The wish to avoid the effects of confrontation and litigation has been a major motivation for partnering.

**Performance**
Empirical evidence on the performance of partnering is somewhat mixed. Larson (1995) found that partnered projects achieve superior results in controlling costs and technical performance and in satisfying customers compared with other projects. However, a US study shows that there appears to be no correlation between the use of alliances (long-term contractual relationships between owners and contractors intended to promote efficiency in capital projects) and project results (The Business Roundtable, 1997). The conclusion is that it is not the alliances but the substance of work processes that produces the result.

**Explanation**
The thrust of partnering is, by attacking the problems created by the temporary organization, to achieve an improved system design. In addition, especially in longer-term partnering, continuous improvement is aimed at. The main focus is on changing human behaviour. However, partnering as such lacks articulated prescriptions at the level of operation, which might explain the lack of impact observed in the study by The Business Roundtable (1997).

**Re-engineering**

**Approach**
Re-engineering (or business process redesign, BPR) refers to the radical reconfiguration of processes and tasks, especially with respect to implementation of IT (e.g. Rockart and Short, 1989; Hammer, 1990; Davenport and Short, 1990). According to Hammer, recognizing and breaking away from outdated rules and fundamental assumptions is the key issue in re-engineering. It was the paper of Hammer (1990) and the subsequent book (Hammer and Champy, 1993) that sparked general interest in BPR. Meanwhile, BPR was developed into a consulting package and it became a buzzword. The first examples of BPR were from administration and services, and this focus prevailed. However, manufacturing companies also started their re-engineering initiatives. Interest in re-engineering also rapidly increased in construction research and practice (Betts and Wood-Harper, 1994; Ibbs, 1994).

**Performance**
Research suggests that re-engineering failed to live up to expectations. Based on data from UK-based organizations, Willcock (2002) found that the majority of re-engineering initiatives in 1994–96 were ‘aiming low and hitting low’. Few organizations were achieving breakthrough results. Obviously stimulated by this lack of success, the fashionability of re-engineering waned towards the late 1990s and it was increasingly discussed critically (Mumford and Hendricks, 1997). Biazzo (1998) comments:
The term BPR has proved to be an attractive banner under whose shade it has been possible to initiate and legitimize even the most disparate projects for organizational change.

As in other industries, the interest in re-engineering seems to have waned in construction towards the end of the 1990s.

**Explanation**
Conceptually and theoretically, the roots of re-engineering are in classical industrial engineering, especially in the notion of process based on the flow concept. In an early contribution, Davenport and Short (1990) even suggested calling the emergent new approach ‘new industrial engineering’. However, the term ‘re-engineering’ (or BPR) became established. The relationship between the flow concept and BPR becomes even clearer when the history of this approach is considered. The idea of business process re-engineering (or redesign) was developed during the study of the impact of IT on organizations by the Massachusetts Institute of Technology (MIT). BPR was defined as one of five levels of IT-induced reconfiguration of organizations (Venkatraman, 1991). It was stated that our current principles of organization are geared towards exploiting the capabilities offered by the Industrial Revolution. It was argued that the IT revolution could alter some of these principles. Close reading of the seminal literature reveals that what were considered to be problems to be addressed in fact were dysfunctionalities caused by the transformation concept, like excessive buffers, fragmentation and inadequate feedback along chains. What was recommended as a solution were process design principles or solutions emanating from the flow concept, augmented with IT capabilities.

Again, the prescription of re-engineering is on the level of system design, and operation as well as improvement aspects are neglected. However, as Weick (2000) argues, incremental improvements are needed both before and after a breakthrough change. The neglect of operation and improvement aspects, together with the lack of explicit theory (Earl, 1994), seems to be among the reasons for re-engineering’s swift loss of momentum.

**Discussion**
For overview, the main results of the analyses are presented in Table 2. As explained above, the focus on structural change is a common feature of all initiatives. With the exception of re-engineering, all initiatives aim at eliminating or alleviating construction peculiarities. In only two cases, comprehensive organizational renewal and re-engineering, are new theoretical concepts of production being introduced to a significant extent.

Why has the success of the initiatives been so modest? Even if the causal relation cannot be definitively established, anecdotal evidence supports the claim that it is the neglect of changes at the level of operation and improvement that has contributed to the relative lack of results.

In addition, industrialization has especially suffered from a narrow theory of production. There is no consideration from the point of view of the F or V concept. The situation is not much better in the case of DB and partnering, where only some elements of the F concept have been introduced.

These findings are compatible with the theoretical framework presented and the propositions derived from it.

**Conclusions**
A renewal of construction should not be based on a prescription based on a partial consideration of the situation – an integrated consideration is needed. First, based both on theoretical and empirical arguments, it is concluded that the
prescription should not be at the level of the production system design only, but rather at all levels: design, operation and improvement of the production system. A theoretical conceptualization shows that structural solutions are just one part of the solution needed. Especially in a complex and uncertain production situation, as usually found in construction, the role of the operation and improvement level accentuates. As could be observed from the examined renewal initiatives, changes at the level of the design of the production system solely bring about only modest benefits.

Admittedly, structural solutions are important, and they may facilitate the implementation of solutions on the level of operation and improvement. However, there are no automatic mechanisms. In contrast to what is often implied, structural solutions do not in themselves lead to new, better solutions on the level of operation and improvement. On the other hand, new solutions at the level of operation and improvement may facilitate the implementation of structural solutions.

Second, the prescription should cover all the three major conceptualizations of production: transformation, flow and value generation. Waste can be minimized and value maximized only through a systematic use of the flow concept and value generation concept, respectively. This conclusion is based on theoretical argumentation and prior empirical studies.

Third, a theoretical analysis indicates that suitable countermeasures should be applied to shield the production system from the performance-decreasing impact of the peculiarities of construction: one-of-a-kind production, site production and temporary organization. Empirical cases suggest this is usually realized by eliminating a peculiarity or all of them, i.e. transforming construction to a manufacturing process. However, such structural solutions solely may not be enough for two reasons, discussed above. First, the need for consideration of the operation and improvement level. Second, the F and V concepts have to be fully deployed; even in conventionally managed manufacturing there is much waste and value loss. Moreover, the elimination of a peculiarity may cause new types of problems. On the other hand, the situation is often such that the peculiarities have just to be accepted.

The definition of an integrated prescription for construction renewal is clearly a complex undertaking. Our present theoretical understanding is not necessarily solid enough. We need to develop fully the theoretical foundation, or first principles, of production in general and of construction especially.

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References


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Endnotes

Groa`k (1994) has rightly challenged the view that construction can be considered as a coherent industry with definable boundaries and characteristic problems. However, what he means by characteristic problems are here considered as peculiarities. The word problem is used here in its everyday meaning, i.e. in this context: low quality, cost and time overruns, and a low safety record. That such problems exist in construction is well known in most countries and thus it is justified to write about problems of construction.
The term ‘production system’ is used comprehensively, especially, it includes the product design phase.

The term ‘variability’ is used here specifically. There are two types of variability in production: process-time variability and flow variability (Hopp and Spearman, 1996). The former refers to the time required to process a task at one workstation, the latter to the variability of the arrival of jobs to a single workstation.

This taxonomy is preferred here to the more popular view of strategic-tactical-operational decision-making, also a temporally based categorization, because of the incorporation of activities after production, namely improvement.

The design of a production system, as a level of managerial action, should not be confused with the design of a product, as a phase of production. To avoid tautology or the danger of confusion, the term ‘structure’ (of a production system) is sometimes used instead.

In the framework of this taxonomy, specific theories for design, operation and improvement of production systems can be developed. In the case of construction, the operation of the production system usually equals project management. For an attempt to clarify the theory of project management, see Koskela and Howell (2002a, b).

For example, from peculiarities listed by Carassus (1998), ‘localized orders of extraordinary diversity’, ‘production of prototypes’, ‘artistic creation’ and ‘localized products which can be durably adapted and modernized’ represent the one-of-a-kind feature. ‘Located on a site’ and ‘itinerant, short-lived, complex and random site work’ represent the site feature, and ‘a producer not controlling the overall process’ represents the temporary organization feature. Only the peculiarity ‘rules and conventions playing a considerable role’ is not covered by this grouping, but this peculiarity is not very significant from the operations’ management point of view.

However, statistical analyses show that one-of-a-kind industries have systematically underperformed mass production industries with regard to profitability (Eloranta and Nikkola, 1992). This has been interpreted to suggest that the production management methods are more geared towards mass production (Ranta, 1993).

It is often argued that construction projects are unique and essentially different from manufacturing in this aspect. However, claims of uniqueness of particular plants also abound in manufacturing (Chew et al., 1990; Plossl, 1991). It seems there is a psychological urge to see one’s own system as unique. In addition, Raftery (1994) has emphasized the large extent of repetition in construction.

However, these characteristics are often not caused by objective conditions but rather are a result of managerial policy aimed at sequential execution and shopping for the realization of various parts of the building at the apparently lowest cost.

For corresponding analyses on the transformation and value concept, see Koskela (2000).

The material flows of construction can be contrasted with those of car production. In car production, material flows can be divided into two types: the flow of components to the assembly line and the (main) flow of the car body through the assembly line. In construction there are three flows. The material flow of components to the site is comparable with that of car production. However, owing to the size of the product, there is an intermediate flow where all installation locations proceed through the installation workstation. In car production, this phenomenon also exists (several seats have to be installed in different places of the car body), but owing to the compactness of (ordinary) cars, all seats can be installed as one operation at one workstation. Lastly, the building frame proceeds through the different assembly phases (processing of all locations by a particular type of workstation(s)) like a car body proceeds through different workstations. Again, a building is immobile, unlike a car body.

Bröchner (1997) shows that the idea of car production as a model for building construction has had a permanent place in the discussion of advancement in construction.

As exemplified in the case of Japanese modular house building where the dimensional tolerance typically is 1 mm.

One further feature of such an integrated prescription, not explicitly discussed here, is that it should cover the total project delivery cycle. As mentioned in endnote 2, the term ‘production system’ is used widely and, in the case of construction, it covers the total project delivery.

An example of a new solution at the level of operation (and also of improvement) is provided by the Last Planner System of production control (Ballard, 2000). This method is compatible with a new theoretical foundation of project management (Koskela and Howell, 2002a).

Here the idea of small wins (Weick, 1984) that form a pattern towards a new system design is especially relevant. For a short discussion of the potential of the Last Planner System to create such small wins, see Vrijhoef et al. (2001).

Initial research is underway to define such an integrated prescription (Ballard et al., 2002; Koskela et al., 2002).