# REVISITING THE THREE PECULIARITIES OF PRODUCTION IN CONSTRUCTION

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## ABSTRACT

Compared to many other industries, construction is a specific type of project industry with certain peculiarities influencing the characteristics of constructed products, ways of production, and the industry itself. Previously three major peculiarities of production in construction have been discussed, i.e. site production (i.e. organising the production around the product dependent on outdoor conditions), temporary production organisation (e.g. fragmented supply chain), and one-of-a kind product (e.g. design-to-order project-based production). Many times, particularly within the realms of lean construction, the basic hypothesis has been that these peculiarities lead to variability and thus to waste, and low performance levels in terms of productivity and value delivery to clients. Inversely, lean construction should be aimed at the banning of waste, thus reduction of variability, and thus the reduction or even resolution of peculiarities.

In this paper, the peculiarities of production in construction are discussed and whether they always cause problems, whether they are always leading to waste, and whether they always can and need to be reduced or resolved. Some examples of solutions resolving or reducing certain peculiarities are given, such as modular housing, pre-engineered buildings and off-site production. Based on the examples, the effects and costs of reduction and resolution of peculiarities are discussed.

To conclude it is discussed whether construction must and can always be improved by resolving the peculiarities, and at what cost. It is concluded that peculiarities should be resolved when they are not needed. However, before to decide to do so, the additional costs or even the potential value loss that may be caused by peculiarities must always be related to the whole life costs and value of the object built, and the extra costs and efforts for resolving the peculiarities. Finally, issues for future research are given.

## KEY WORDS

Construction, Peculiarities, Repetitiveness, Resolution, Waste.

## INTRODUCTION

The construction industry has often been observed and criticised for its supposed low performance and many problems, and even accused to be backward (e.g. Vrijhoef & Koskela 2005b; Woudhuysen & Abley 2004). Causes for the problematic character of construction have been searched at the level of the product, the production in projects, as well as the industry as a whole. In this paper, the main focus is on the production in construction. Although, product and industry characteristics do have their influence on the production situation in construction projects, and the production environment of construction in general.

Alternative approaches to production in construction have been presented in theory and in practice many times to improve construction by

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resolving or reducing peculiarities[3] of construction. For instance, already in 1967, Turin (2003)[4] presented three alternative approaches compared to the traditional 'one off' approach: the 'component' approach, the 'model' approach, and the 'process' approach. The component approach implies a repetitive approach to construction on a component level (standard components, pre-engineered buildings), related to another existing concept of 'mass production new style' (Drucker 1963). The model approach implies a repetitive approach to construction on the complete product level (standardised end products, catalogue buildings), related to Drucker's idea of 'mass production old style' (Drucker 1963). Turin's fourth approach, the 'process' approach, is representing the introduction of standardised or repetitive processes, rather than standardised components or products.

To some extent the solutions envisaged by Turin have certainly been implemented, but progress has been slow in most cases, and the majority of construction work is still done in a fairly traditional way, although examples of new approaches and improved working methods can be spotted. These new approaches are implicitly or explicitly aimed at the resolution of the three peculiarities of production in construction: site production, one-of-a-kind production, temporary organisation. This paper tries to shed new light on these issues, especially by widening the explanation of the existence of the peculiarities, and by analysing the possibility of selective elimination or alleviation of peculiarities.

## UNDERSTANDING PECULIARITIES OF PRODUCTION IN CONSTRUCTION

The peculiarities of production in construction could be explained and understood separately, and be studied in an isolated way. However, we contend that the peculiarities of production are interlinked by causal relations. Peculiarities on the production level are related to peculiarities on the product and industry level (Figure 1). Particularly for certain subsectors of the industry and certain project types, peculiarities on the product and industry level, such as discontinuity in demand and large and complex projects, can lead to all kinds of effects on the production level. The three levels of peculiarities reinforce each other in a complex interaction, which contributes to the difficulty of reducing any peculiarity and thus also to the persistence of the problematic character of construction.

### PRODUCT LEVEL

The basic characteristics of constructed products have been viewed to cause limitations to technology and problems to management of construction projects (Nam & Tatum 1988). In this context, various features have been mentioned, such as immobility, complexity, long product life cycles, high capital intensity and high impact on the surroundings. In addition, constructed products are often unique objects with additional specific features, and they have been built in a specific institutional and socio-economic context.

### INDUSTRY LEVEL

At the industry level, there are high levels of fragmentation, high variety of firms of different specialisation and size, and high levels of casualisation of labour. By some it was even questioned whether construction is actually an industry (Groák 1994), or rather a 'loosely coupled system' of projects (Dubois & Gadde 2002). However, paradoxically, fragmentation of the industry must not be seen problematic as such, and the involvement of many different specialised firms in projects does not automatically lead to low levels of efficiency, but instead may increase efficiency of resource allocation and speed of information exchange between parties (Pryke 2002).

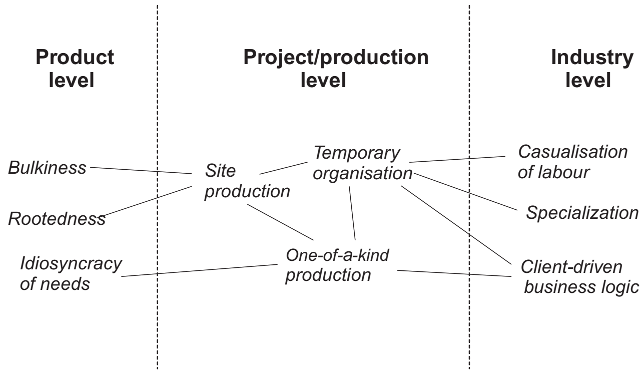


Figure 1: Peculiarities of construction on product, project/production and industry level

Product and industry characteristics do have impact on the production situation of construction, and the way production in projects has been organised. In this paper the main focus is on the production level (Figure 1). Below, the three

3 In this paper we use the term peculiarities, rather than terms such as constraints or problems, because peculiarities refer to characteristics that may but do not necessarily lead to constraints or problems.

4 Reprint of the original article first published in the Proceedings of the Bartlett Society in 1967.

peculiarities of production in construction, and their interdependencies are further explained. The explanations are meant to find first implications of improvement of production in construction by resolving the three peculiarities (Figure 2).

## PRODUCTION LEVEL

Construction projects have been described as coalitions of firms; 'a number of independent firms coming together for the purpose of undertaking a single construction project and that coalition of firms having to work as if it were a single firm, for the purposes of the project' (Winch 1989). Alternatively, the parties involved in construction projects have been interpreted as 'organisational units joining and operating together as a single production organisation when it is advantageous' (Harland et al. 1999); a 'temporary multiple organisation' (Cherns & Bryant 1984); or a "quasi-firm" (Eccles 1981). The production system in construction could be characterised as engineer-to-order (ETO) (Ballard 2005), or assemble-to-order (ATO), based on "capability-oriented production" (Wortmann 1992). Alternatively, construction could also be observed as a design-to-order, or even concept-to-order kind production system. (Winch 2003). At the level of project/production, three main peculiarities have been identified: site production, one-of-a-kind production and temporary organization (Koskela 2000). Such basic problems are difficult to resolve, including the causes behind them and the deficiencies stemming from them (Vrijhoef & Koskela 2000).

### Site production

Whether it is site installation of prefabricated parts or a complete prefabricated building on site, or merely construction on site, production in construction is always locally bound and dependent on physical factors such as soil and weather conditions. This is also true for some other industries, as discussed above. However, compared to most other industries the volume and repetitiveness of projects and products in construction is extreme low, and one-off in most cases. The organisation of production and the supply chains is strongly aimed at the convergence of logistics to one site, and delivery of the one-off, and often highly customised and capital intensive product to a single end customer (Lin & Shaw 1998).

### One-of-a-kind production

Most built objects are relatively unique products; not only because they are being designed as a unique product, but also because the context of every built object and the construction process is always different; location, economic situation, environment, institutions etc. This has been identified as a the 'one-off approach' (Turin 2003), reflected most characteristically by the predominant one-off approach in discrete construction projects, or 'unique-product' production (Drucker 1963). This may be called the "prototype nature" of construction (Koskela 2000). Construction can be typified as a specific kind of project-based industry. 'Treating construction as a type of manufacturing obviously neglects design, and arguably subordinates value generation to waste reduction, which inverts their proper relationship', however 'certain aspects of construction should move into the realm of repetitive making' (Ballard 2005).

### Temporary organisation

As a result of the predominant focus on site production and one-of-kind products, construction is usually organised in temporary organisations for purpose of separate projects. This is not often based on mere objective grounds, but rather managerial habit aimed at sequential execution of projects and financial optimisation of parts of projects. Firms of many different kinds and different people are teaming up for every project again. Not supporting knowledge transfer and systematic and long-term approaches to production and improvement. This relates to the one-of-a-kind nature of construction. Grouped organisations which have had no prior collaboration are mostly operating less efficient and effective than steady organisations. Often the setup and changes of the collaboration requires relative large amounts of effort, time and thus costs before the project organisation is operational (Koskela 2000).

Understanding temporary organisations can be hard because of their changing nature. Therefore contextual perspective of these kinds of organisations is important and helpful. Furthermore understanding temporary organizations needs a focus on action, and explanations of temporary organizations must encompass action (Action-Based Entrepreneurialism). Action is the essence of temporary organizations (Lundin & Söderholm 1995; Lundin & Steinthórsson 2003).

### Relation between project/production peculiarities

The three peculiarities of construction show a logical relation and causality (Figure 2). Built facilities i.e. constructed products are physically and structurally "rooted" in the ground, and therefore at least a part, and traditionally the largest part of the work is done on site. As a result of the fact that constructed products and construction is always connected to a particular place including the physical, economical, social, political etc. context, constructed products are always unique, and therefore construction is always one-of-a-kind to a certain extent. As a result of the basic one-of-a-kind nature of construction the organisation of the production in construction is always project-based and thus temporary for a part at least, and traditionally for a large part.

Consequently peculiarities should be resolved or minimised in an integrated way if "full resolution" of waste stemming from the peculiarities is pursued. Because of the complexity of the production situation as well as the production environment of construction "full resolution" is mostly not the case, but rather "partial reduction". Later on in this paper, some examples are presented that show "partial reduction" or better management of peculiarities.

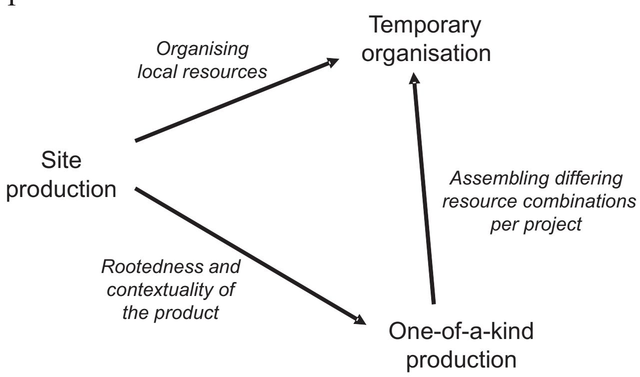


Figure 2: Relations between project/production peculiarities

## FURTHER OBSERVATIONS ON THE NATURE OF PRODUCTION IN CONSTRUCTION

### PRIOR THEORETICAL AND EMPIRICAL OBSERVATIONS

These observations need to be put into the perspective of construction, and the specific features of construction, particularly compared to other kinds of production[5]. Ballard and Howell (1998) stated that construction is a fundamentally different kind of production. In essence, construction is the design and installation of objects on a fixed place. Consequently, to a certain extent, construction is always about site production on a certain location, and for that reason always unique. Often the technological requirements of projects also vary considerably, which requires mobilisation of temporary teams with specific technological capabilities. Generally there are two paths to reduce negative effects of the relatively unstable production situation in construction. The first is minimising construction's peculiarities in order to take advantage of techniques and methods for instance developed in manufacturing to simplify site construction and increase prefabrication and standardisation. The second is developing techniques within construction itself that are able to cope with the dynamics of construction (Ballard & Howell 1998). The central question is what the relationship between these two paths is. There has been various movements arguing, for example the Egan report in the UK, that for lean construction to be realized, construction must first be transformed into manufacturing. On the other hand, it has also been argued that for being able to "industrialize" construction, first the processes in construction must be controlled, which is a lean target.

Koskela (2000) concluded that we should accept the hypothesis: construction peculiarities contribute to waste and value loss, and it is necessary to eliminate or reduce them or to mitigate their impacts on the level of control and improvement. However, in view of his case findings, the situation seems often to be such that a peculiarity has to be mastered at the levels of design of the production system, production control and improvement. This is because it is seldom possible to eliminate a peculiarity totally. Also he found indications that the elimination of a construction peculiarity has a price: the characteristics of the production system may change so that new problems 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 (Koskela 2000). Thus, the claim is that the structural elimination of a peculiarity does not necessarily by itself solve the problem, but a wider approach is needed (Koskela 2003). However, the empirical material used in (Koskela 2000) was relatively small. Also, the question whether the peculiarities are such extent interdependent that they should be

5 Of course, it can be asked what we are taking as the benchmark when discussing construction peculiarities. Implicitly, we mostly think of manufacture of similar products in a factory by a permanent organization as the normal, and construction seems to deviate from this in critical points, which we thus define as the "peculiarities". Thus there may be a bias towards manufacture in how we conceive construction peculiarities. The discussion and the results would probably be different if the benchmark would be another sector, for instance agriculture or mining.

eliminated en masse or whether they can be eliminated selectively was not addressed.

**ARGUMENTS FOR IMPROVEMENT OF CONSTRUCTION BY RESOLVING PECULIARITIES**

The first question here is why we should try and improve construction by resolving peculiarities of production in construction in the first place? The basic argument is that peculiarities that cause production problems and "waste", which is not needed, must be resolved or reduced. But peculiarities do not necessarily have to result in production problems, leading to waste. And then these questions arise: Are peculiarities regarded as problems and waste? What are the extra costs and efforts to resolve or reduce the peculiarities, particularly in relation to life cycle costs and revenues? Some non-value adding activities which are not basically part of production often represent and business functions that are just needed and planned for doing business in general; such as transport, administration, marketing, sales, HRM, quality management etc. Must these activities be considered as waste, or not; and thus always be resolved or reduced, or not?

**TENSION BETWEEN WASTE RESOLUTION AND VALUE DELIVERY IN CONSTRUCTION**

The definitions and relation between waste and value depend on many aspects, such as the type of construction and types of projects; from simple and normal projects to complex and extreme projects. As such, it is impossible to speak about the construction industry and construction projects in general, while the industry consists of a vast spectrum of different subsectors and professions, and different types and contexts of projects. Sometimes achieving value (economic, environmental, social, cultural, historic) is more important than reducing waste (operational, production). Some examples of projects have shown huge waste in terms of production, but have represented great cultural and historic value, such as the opera house in Sydney. So it is not always clear whether the value produced can be related to the waste caused.

This has also implications for the way to look at construction peculiarities. What peculiarities are leading to waste, and what to value? And additionally, how peculiar are the peculiarities of construction related to other industries, for instance the location bound features of construction can be also be found in mining, agriculture and offshore. In general there is a need for a more balanced discussion about what purpose of construction is, what value and waste is, and what the impact and problems of peculiarities are. One must observe

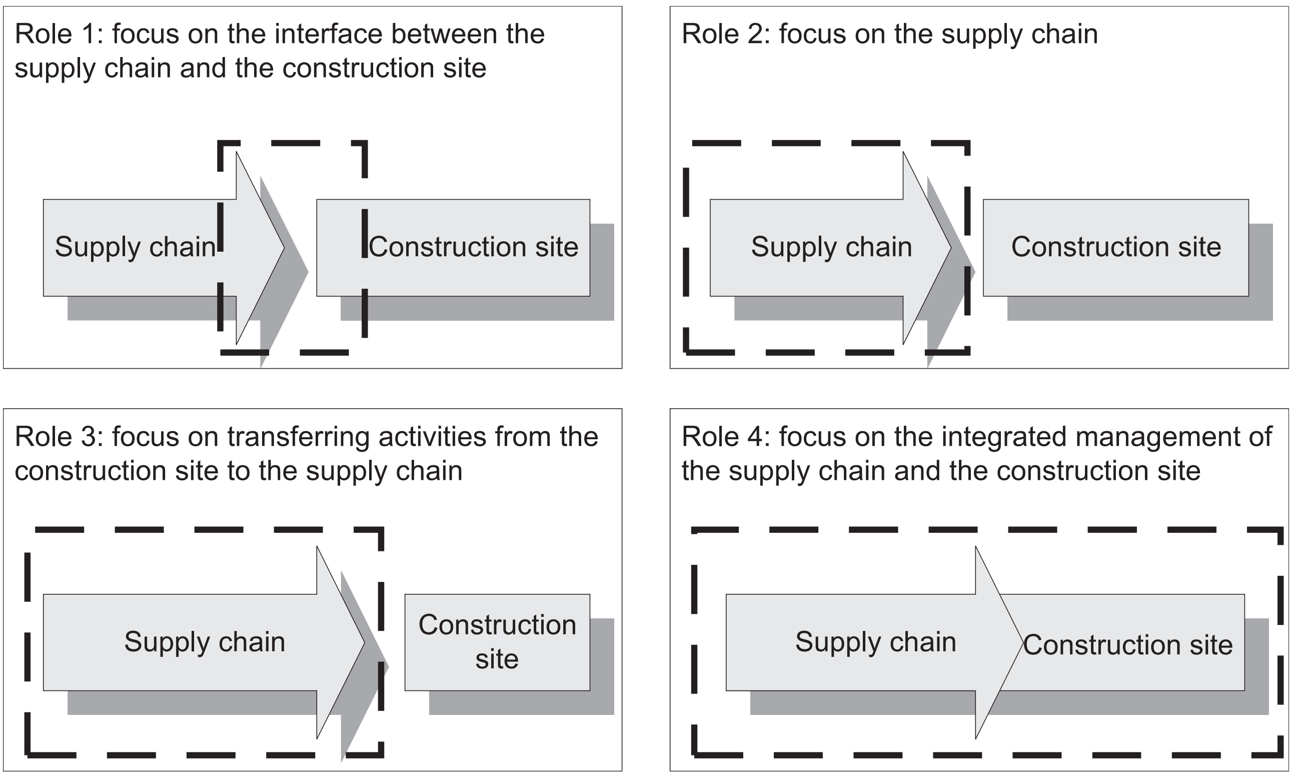


Figure 3: Four roles of supply chain management to integrate the supply chain and the construction site (Vrijhoef & Koskela 2000)

construction in wider perspective, not just getting a construction project done with most efficient use of means, but also aimed at delivering value to clients, users, stakeholders and society in general.

## RESOLVING PECULIARITIES OF PRODUCTION IN CONSTRUCTION

Construction clients and supply chain parties have reacted to peculiarities of construction, and developed various strategies to cope with the effects of the peculiarities in their businesses and processes. Project-independent approaches to construction have often been advocated and applied as a way to solve the problematic effects caused by peculiarities of construction, particularly related to one-off production. Alternative approaches were also aimed at stabilisation of the project and production environment, by increased off-site production and multi-project organisations. From a supply chain perspective, this implies increased levels of integration and alignment between the different "stages" in the supply chain, e.g. between the materials supply and the construction site. These approaches are thus mainly aimed at the resolution of the site production peculiarity, but also imply resolution of the temporary production organisation (Figure 3).

### EXAMPLES OF RESOLVING PECULIARITIES OF PRODUCTION IN CONSTRUCTION

In practice, various examples can be found were parties in construction (clients as well as supply chain parties) have explored ways to reduce the impact of peculiarities of traditional construction on their projects and businesses. Often this implied different ways of delivering and procuring construction work, and often parties involved introduced new ways of procurement, management and doing business. Below seven examples are given of resolving different combinations of peculiarities. Thus all examples have resolved or reduced one or more of the three peculiarities to a certain extent. The examples are illustrative for the different levels and manners to resolve or reduce peculiarities in practice (Table 1).

These cases give added evidence of the manifestation of the peculiarities, and the ways to resolve or reduce them. First, it is possible to achieve production improvement and create competitive benefit by eliminating or reducing one or more peculiarities. Second, it is possible and advantageous to selectively eliminate a peculiarity, although other peculiarities remain in place. However, all cases imply moving away from the traditional approach, which is leaving all peculiarities untouched. Often the companies involved have chosen to focus on a certain niche market, where they have been more successful and more competitive, than traditionally operating competitors.

Most cases imply a certain increase of the level of repetitiveness of construction. Some of the companies involved have increased the repetition factor between projects by developing and introducing complete product concepts (e.g. housing concepts), or integrated components of building to the marketplace including all engineering, parts manufacture, logistics and site assembly (e.g. integrated facades for offices), rather than delivering one-off projects, based on mere project specifications. Still traditional construction practice is dominated by one-off approaches and ad hoc production organisation, which will continue to be needed in many cases in construction, for example for complex and large projects, and special projects in specific situations.

### DOES RESOLUTION OF PECULIARITIES LEAD TO IMPROVEMENT OF CONSTRUCTION?

In general, resolution of peculiarities results in less problems, or less effort needed to manage peculiarities. However, the resolution of peculiarities through business process reengineering or fundamental change of the production system often requires investments, and extra effort to implement new production methods and techniques. So the issue to resolve or manage peculiarities is a trade-off in essence between benefits and investments.

Furthermore, the argument that the structural elimination of peculiarities does not necessarily solve the problem by itself is most actual here. This was illustrated in a recent study (Rintala 2004), aiming to generate a detailed understanding of how the economic efficiency of an accommodation service PFI project is determined in its development process through CWLC (Contract Whole Life Cost) minimisation. The study focused on heating and ventilation. The conclusion was that not a single whole life cost driven design solution could be identified in the heating and ventilation design solutions of the case study projects. The comment was: 'Initially, in both case study projects, the PFI projects had the opportunity and the incentive to implement life cycle performance driven design solutions. However, as the development of the projects progressed, the opportunities became constraint and the incentives weakened. This was a result of the way that the PFI project actors organised themselves' (Rintala 2004).

Table 1: Practical examples of resolving peculiarities of production in construction

| Example | Description | One-of-a-kind | Site | Temp. org. |
|---|---|---|---|---|
| Prefab modular homes | Sekisui Heim has developed a housing concept that is built from standardized modules and parts, providing a limited collection of house models, which are fully pre-designed based on latest trends and lifestyles. The houses are completely prefabricated off site, and installed in modules. The organization of design, engineering, fabrication and installation is fully predefined and standardized for all projects (www.sekisuiheim.com). | X | X | X |
| Site factory | Few construction companies have developed temporary technical solutions to reduce or shield the work on site, e.g. “site factories”. Examples are large tent constructions to shield house building on site, and rising factories for high-rise building (e.g. Big Canopy, Obayashi Corporation), temporary concrete factories on site (e.g. for fabrication of elements for tunnel building). | X | X | |
| Standardised homes | IKEA and Skanska have developed a standardised housing concept (Bo Klok). The design is largely standardised, partly preinstalled, and always installed by fixed crews on site. | X | | X |
| Pre-designed buildings and homes | Various companies offer pre-designed and pre-engineered buildings such as small business halls and offices, and houses. The design is mostly standardised in few types with few possible modifications. The products can be bought by client as standard packages. The products are often prefabricated, but site installation and organisation are to be organised separately. | X | | |
| Open building | Open building has mainly been applied to housing. The design is fully customised based in clients/users wishes, particularly the interior. All parts are prefabricated and preinstalled in the factory. Multi-skilled fixed crews install the houses on site (Dekker 1998; Vrijhoef et al. 2002) | | X | X |
| Prefab office building | In 2001 the Bollard office building was designed, engineered and constructed completely using offshore technology and expertise, and transported as it were an offshore platform, and craned into place on its final destination. The office was built completely off-site in an offshore plant by an offshore platform contractor, and transported by a heavy-duty open sea transportation and salvage company (Maas & Van Eekelen 2004). | | X | |
| Co-makership in housing | Few main contactors particularly in housing apply strategic collaboration between with their subs and suppliers to achieve process repetition. Still the projects are dominated by traditional one-off and on-site production. | | | X |
| Traditional construction | N/A | | | |

## DISCUSSION AND CONCLUSION

In current practice the peculiarities of construction are still widely present. In many cases parties have made an effort to resolve, reduce or better manage the peculiarities. Only in a few cases the peculiarities have systematically been resolved. Peculiarities of construction are not always a problem, or perceived as a problem, and not always leading to negative effects and waste. Therefore there is not always a need to resolve or reduce peculiarities of construction, in order to improve construction. However, peculiarities can be advantageously resolved in a selective mode by altering current processes, and sometimes even shifting business to new (niche) markets. The peculiarities of production in construction are causally related or reinforced by peculiarities of constructed products and the construction industry, which makes their resolution often more difficult. Therefore peculiarities are often not resolved, but rather reduced or better managed. Resolution needs fundamental change and restructuring on the production level, and can not be done by indirect methods such as alternative financial or procurement routes such as PFI. Peculiarities are essentially locked in and subconsciously present in the industry. Peculiarities are part of the historically grown paradigm of the industry. This is logical as such, but also hard to explain and to grasp. But on the other hand, when this causes inefficiencies and waste, it is not logical from an economic point of view.

Peculiarities are not equal to problems or waste. When peculiarities lead to problems and waste, obviously, they need to be better managed, reduced or ideally resolved. But in some cases peculiarities of production in construction must be accepted, including the production problems and waste, when there is no interest to resolve them by any party who would need to make investments and efforts to resolve the peculiarities. This must particularly be seen in relation to the total value of the constructed object through the whole life cycle, taking into account all value aspects; economic, environmental, social, cultural, historic (the "bigger picture"). Because of this wider impact of construction on society, value is often much more important in construction than reduction of waste and costs. From this higher abstraction level, the construction of a built facility is often seen as just an "incident" in the life cycle; waste is seen as an "operational problem" for the supply side. And by taking some measures or following another business model it should possible to reduce waste rather easily. This kind of notions of waste reduction versus value increase, in relation to the questions whether to try and achieve reduction or resolution of peculiarities and improvement of production in construction, should have implications on the development and implementation of lean in theory and practice.

## ISSUES FOR FURTHER RESEARCH

Still, it must be concluded that resolution leads to improvement and higher performance of production in construction when these peculiarities cause any kind of waste (Koskela 2000). But then it must be debated whether improvements and benefits can only be achieved when peculiarities are resolved or reduced; which is not always necessarily the case. In some or even most cases it would be more logical just to accept and better manage peculiarities. This depends on the need and extent by which current practice is restructured and improved, often not necessarily needing revolutionary change and going down the lean route to achieve projects that are well managed, to time and budget, and value delivered according to clients' wishes. And the issue arises whether it is matter of resolution or reduction, or better management of peculiarities; the boundary between these is debatable too. It is partly an issue of terminology; where does managing stop, and does resolving start. Many examples in construction show incremental change, based on improvement of current practice leaving the peculiarities of construction as such largely untouched. Actually a large part of the lean construction movement has also taken construction as it is, and trying to improve construction within the context of the existing production situation, e.g. improving planning systems to increase productivity.

The issue of peculiarities of production in construction has invoked comparisons with other industries, where the level of repetitiveness is normally higher. Thus, mainly, these comparisons include a discussion of the peculiarity of temporary organisation of construction, and whether and how this can be reduced by the concept of repetitiveness, both in terms of repetitive technology and products as well as repetitive processes and project organisation. The concept of repetitiveness and finding or developing concepts and methods that increase the level of repetitiveness may well be the path to follow for further development of production management in construction. Comparisons with other industries may be helpful; whether these are other project-based industries, manufacturing industries or service industries (Vrijhoef & Koskela 2005a). The usefulness of applying concepts from various other industries has been discussed and demonstrated before, such as automotive, aerospace, electronics (Gann 1996; Voordijk & Vrijhoef 2003; Vrijhoef & Voordijk 2004). It has been discussed also that translation is needed when studying the possible transfer and application of "exotic" concepts to a construction context (Koskela & Vrijhoef 2001), by learning from other industries how to cope with construction peculiarities, without being "over-simplistic" (Green et al. 2004).

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