STRUCTURAL AND CONTEXTUAL COMPARISON OF CONSTRUCTION TO OTHER PROJECT-BASED INDUSTRIES

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ABSTRACT: Like in other project-based industries construction supply chains are generally started for different projects, in an one-off multi-organizational setting. This has often been observed as a typical feature of construction practice. However it has also been discussed many times as a characteristic that particularly is causing high levels of ineffectiveness and inefficiency in construction supply chains. Production and operations management and supply chain integration concepts from other project-based industries such as aerospace and offshore may be transferable and applicable to construction, improving the effectiveness and efficiency of construction practice. In this paper the configuration and coordination of the supply chain including the management of operations and production in various project-based industries are analysed and compared to construction. Differences and similarities between the industries and construction are observed, in relation to the specific industrial structure and contexts of the respective industries vis-à-vis construction. The analysis indicates the impact and supply chain improvement potential of the various production and operations management and supply chain integration concepts that were found in the respective industries, in relation to current construction practice. Based on the example findings of one "non-conventional" example of construction, the applicability of the production and operations management and supply chain integration concepts from the offshore industry to construction is assessed. Taking into account the basic structural and contextual differences and similarities, the feasibility of transfer and application of industrial concepts, found in terms of supply chain integration and production and operations management concepts to construction, and the implications for improvement effectiveness and efficiency of construction are identified.

Keywords: aerospace, comparison, construction, offshore, project-based industries, supply chain.

1. INTRODUCTION

The historic and economic developments of different industries have caused typical structural and contextual differences between industries and the common production situation within these industries. Differences relate to structure (firm size and types), culture (common practice) and management principles (business and production methods). Based on structural, cultural and management characteristics, some industries are considered to be advanced compared to others. In some cases it is worthwhile to study the differences between industries and look for possibilities to learn from other industries and transfer management principles from one industry to the other. Often these management principles need to be translated in order to be transferred. In most cases not a complete management concept is transferred, but the underlying principle is taken and parts of the concept are transferred. Often the transfer is aimed at improving current practice in an industry rather than introduction of complete new production system or business concept. Thus in most cases the transfer of concepts implies incremental innovation rather than radical change.

2. TYPOLOGY OF PROJECT-BASED INDUSTRIES

Characteristics of project-based industries vary from industry to industry. The production system of each industry, or even the different systems of each sector within one industry, has been shaped by the industry characteristics and history. Project production systems in project-based industries are aimed at a product mix that is 'one of a kind or few', process patterns are 'very jumbled', processes segments are 'loosely linked', and management challenges are dominated by 'bidding, delivery, product design flexibility, scheduling, materials handling and shifting bottlenecks' (Schmenner, 1993).

Construction can be typified as a specific kind of project-based industry. Ballard (2005) relates construction to engineer-to-order products (ETO) viewing construction as a type of project-based production system, instead of a type of manufacturing. '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). Production system types of different industries could be dominated by either (one-off) designing or (repetitive) making (Figure 1).

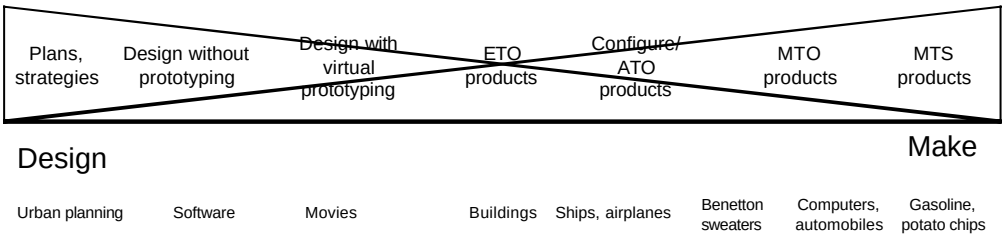

Figure 1: Production system types (Ballard, 2005)

The production situation in construction could also be related to assemble-to-order production and "capability oriented production" systems (Wortmann, 1992). Alternatively, construction could also be observed as a make-to-order, design-to-order, or even concept-to-order kind production system (Winch, 2003) (Figure 2). The characterisation of the production system of construction is largely dependent on the view taken and the definitions used.

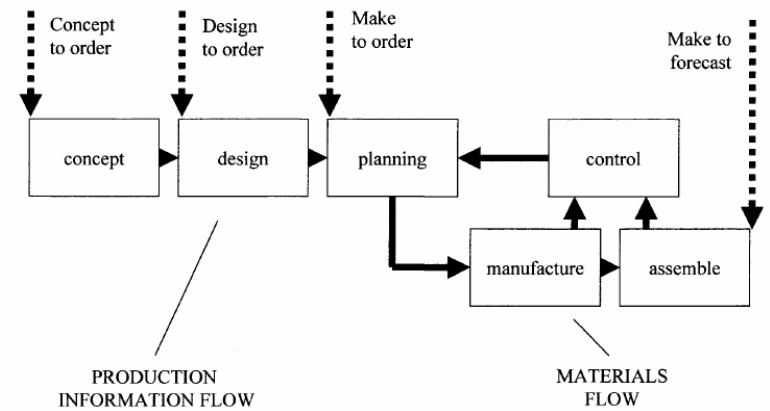

Figure 2: Production systems in construction (Winch, 2003)

When observed from a make-to-order perspective, the main management challenge is to capture the client order, avoid problems on interfaces in the supply chain and reduce time buffers in the information and materials flows (Luhtala et al., 1994). In addition, compared to

other project-based industries, whether it is site installation of prefabricated parts on site or mere on-site production, production in construction is always locally bound and dependent on physical factors such as soil and weather conditions. In addition, compared to most other project industries the volume and repetitiveness of projects in construction is mostly extreme low. The organisation of production and the supply chains is strongly adapted to these basic characteristics, and 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) (Figure 3).

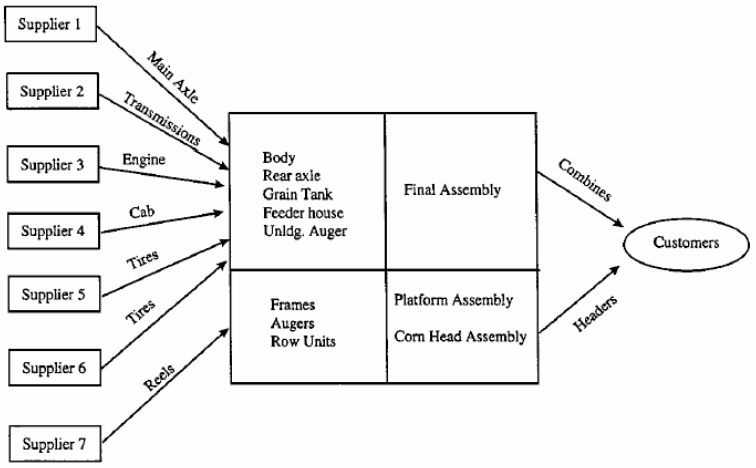

Figure 3: Convergent supply chain (Lin & Shaw, 1998)

3. THE NATURE OF CONSTRUCTION AS A PROJECT-BASED INDUSTRY

The characteristics of the construction industry have often been observed, although in some cases even it was even questioned whether the construction is actually an industry as such (Groák, 1994), or rather a "loosely coupled system" of projects (Dubois & Gadde, 2002). In these observations the nature of construction and particularly the strong project focus within the industry has often been identified as a basic cause of many of the limitations and problems of the industry (Nam & Tatum, 1988). Some have identified specific peculiarities of construction causing the problems, including the temporary organisation, one-off product and site production (Koskela, 2000).

Winch (2001) indicated the problem of the fragmented character of project governance of construction, and identified the need for a common conceptual framework for the governance of transactions through the construction project lifecycle combining specialists in different areas who are involved in the project governance. Besides the high levels of fragmentation in terms of types of firms, also the broad spectrum of firm size and the relatively high rate of SMEs in construction increase the complexity of the industry structure, and complicate the contracting and control of construction projects.

The broad and heterogeneous firm demography of the industry implies the presence of many firms of different size and type. Particularly in large construction projects this is complicating the management of these projects and the supply chain (Vrijhoef & Tong, 2004). Moreover, Phua (2004) identified significant differences between different types of firms in terms of what they regard as important to project success. The determinants of project success show to be not always straightforward and identical. The view on and the approach to project success is a result of the process in which parties are involved, and the interaction between those parties and numerous external factors, which is affecting the behaviour of parties, and thus the process and the project. The customer for instance may

have a completely different view on the success of the project than the contractor. The customer may define project success in terms of economic benefit experienced from the building during the life cycle. The contractor may consider the project successful when it has been delivered on time and within budget. In addition, the many other parties involved in construction projects may have different expectations about the project success.

4. COMPARING INDUSTRIES: CULTURE, STRUCTURE AND MANAGEMENT

4.1 Cultural aspects

Culture in construction has significant differences to that found within other industries, e.g. manufacturing. For this reason application of management concepts from other industries needs substantial reconceptualisation of these concepts. The culture in construction is rather multiform and inhomogeneous, caused by the relatively high fragmentation of the industry in different types and sizes of firms, and necessitated by the varying organisational configurations of projects. The culture within construction is a typical "project culture" and is often relatively informal compared to the often more formal "corporate culture", which has dominated in other industries such as manufacturing, and the utilities and services sectors. In addition, because construction projects usually involve a large amount of subcontractors, i.e. many external people, main contractors have to rely on a relatively strong project hierarchy and intensified management effort to achieve sufficient levels of integrated project culture or quasi-corporate culture, shared values, corporate memory and uniformity of management that is needed for project success.

The high status of projects explains the existence of two cultural identities within the construction industry: the corporate culture (office), and a distinctive culture within each separate project. The rather strong disconnection between the more regulated office environment and the less regulated project environment often disenables corporate innovation programmes effectively reaching the production on site (project). However on a construction site workers are continually producing new solutions to problems that occur on site every day, but may be taken for granted, and not regarded, managed and communicated as an innovation. This explains why construction industry is deemed being less innovative than for instance manufacturing. The fragmented production system, strong influence of project culture, relatively weak corporate culture, and lack of shared values particularly among subcontractors is also regarded as a reason for the low customer focus and lacking possibilities to achieve value for the client. Main contractors must try and manage the rather random nature of subcontractor, which is amplifying the negative effects of project culture. Improved relationships, increased levels of supply chain integration and partnering with subcontractors should be aimed at increasing the identification of subcontractors with the main contactor's values, culture and the ultimate goal to achieve project success and customer value (Riley & Clare-Brown, 2001)

Because of the central role of projects in construction, the project management function and the project manager have an important role. In fact the project manager who has the responsibility for the design as well as the execution, matches the project and the customer needs, and takes care of the entire production management. The dilemma is that the more complex and large the project is, the more empowered the construction manager must be to exercise control and authority, but also the more he should delegate and trust his people (Hammuda & Dulaimi, 1997).

4.2 Structural aspects

The construction industry makes significant contributions to the social, environmental and economic development of society. The importance of the industry in the economy is relatively large; in most regions in the world about 10% of GDP direct contribution, and also a significant indirect contribution. The indirect contribution is caused by effects of construction in other sectors through a complex system of connection to these sectors, such as materials, chemicals, banking and other services. Most causal relationships between construction and other sectors are bi-directional, for instance in the case of technological innovations in certain sectors, or economic and political developments in certain regions. This means that relationships between sectors are complex, and that construction has a multiplied effect on other sectors and the economy in general (Lean, 2001).

Project characteristics differ noticeable across project-based industries. In financial terms usually the normative resource in construction projects is the budget and the completion date. The project success measure is cost, and completing the project by the scheduled date is often the most important scheduling objective (Tukel & Rom, 1998). Although this will be not quite different in various other project-based industries in general, there are differences in scope, for instance in the movies and software industries, where the emphasis is far more on the profits to be made when a movie or software is distributed and rights and royalties are yielding revenues.

4.3 Management aspects

The types and standard of project management techniques differ between different industries. For instance petrochemical and defence industries use relatively highly developed project management models. The models used in construction industry are relatively basic and tend to have similar characteristics for all types of projects, compared to other more high-tech industries. Project management in construction is relatively highly dependent on personnel skills and experience of project managers instead of dominated for instance by the use of sophisticated project management systems. Also the relatively low level of competition and the economic stability in construction have played a role here. On the other hand, in the petrochemical industry the high standard of project management has been influenced by the pressure on reduced costs of oil exploration and extraction due to the low oil price in the 1980s, for instance in the case of the offshore operations on the North Sea during the 1980s and 1990s, which lead to joint project initiation such as in the CRINE programme (Cost Reduction in a New Era) (Cooke-Davies & Arzymanow, 2003).

Compared to utilities, pharmaceuticals and manufacturing, Wirth (1996) found relatively low levels of project manager qualifications, project size and uncertainty characteristics in construction. Consequently, it would be seem feasible to transfer project management capabilities from other industries to construction, than in the opposite direction.

In terms of quality management, Lai and Cheng (2003) found that significant contrast exists between industries with regards to the level of quality management implementation and quality output performances. Levels of quality management implementation and the emphasis on quality management in construction (and manufacturing) companies is relatively low compared to utilities and service companies. In construction and manufacturing the attitude tends to be oriented towards conformance to contractual specifications and not gaining additional financial benefits or competitive strength from quality improvement. Construction and manufacturing were observed to be less customer-oriented or responsive, but oriented more towards production and getting the work done on time and within budget. Particularly in construction the management challenge is mainly focussed on projects, which together

with the relatively informal culture, and the fragmented structure of the industry as a whole as well as the production system, causes basic differences with other technology-driven industries, and particularly with non-technology industries (Table 1).

Table 1: Construction compared to other technology-driven industries and non-technology industries

	Construction	**Other technology-driven industries**	**Non-technology industries**
Culture	Informal	Formal	Dynamic
Structure	Fragmented	Consolidated	Integrated
Management	Project driven	Process driven	Customer driven

5. CONSTRUCTION COMPARED TO TWO OTHER PROJECT-BASED INDUSTRIES: OFFSHORE AND AEROSPACE

When construction is compared to other industries, on a general level large economic differences can be observed. These differences are to be taken into account when comparing the management practices within the industries, and studying the transfer and application of these principles from the one to the other industry. Here construction is compared to offshore and aerospace. Notable, in Europe, the annual turnover of construction is considerably larger than aerospace and offshore, and so are the numbers of companies and employees. In addition, the large number of SME's and very small companies under 20 or even 10 people are indicative for the high level of fragmentation of the construction industry (Table 2).

Table 2: Key figures of the European construction, offshore and aerospace industries

	Construction (2003)	**Offshore (1997)**	**Aerospace (2002)**
Turnover	€ 910 bln (EU-15; 9.8% GDP)	€ 16.4 bln	€ 74.6 bln
Profit / value added	2.2 %	6.9 bln direct VA (6.4 bln indirect VA)	4.6% profit of turnover
Nr of companies	1.8 mln (97% < 20 empl; 93% < 10 empl)	Approx 300	750 (526 < 250 empl)
Nr of employees	11.7 mln (EU-15; 7.1%)	144,000	407,800 (0.2%)
Source:	FIEC www.fiec.org	NML EU report 2001	AECMA www.aecma.org

5.1 Applying offshore engineering and production techniques and logistics to an office building

The offshore industry has been known for the complex engineering of large oil and gas platforms, and large-scale operations on open sea where to construct the platforms from large prefabricated parts. Because of the small size of the oil and gas industry in terms of numbers of companies, and the high environmental impact of the industry technological and environmental issues have played more important role than procurement issues compared to other industries. Due to further competitive and safety challenges the importance of procurement and outsourcing strategies has risen (Mohammad & Price, 2003). Project alliances in offshore have been discussed including mechanisms to share project risks and rewards between operators (oil and gas companies) and offshore contractors and potentially reduce project costs and enhance profits (Halman & Braks, 1999).

In 2001 an office building near Rotterdam in the Netherlands was designed, engineered and constructed completely using offshore technology and expertise, and transported and put in place on its final destination as it were an offshore platform. The project was constructed completely off-site in an offshore plant by an offshore platform contractor, and the transport was done by an offshore and heavy-duty open sea transportation and salvage company (Figure 4). The latter is also the client of the office building, who is currently using the office as its head quarters. Besides extraordinary, the project was extremely successful in terms of lead times and client satisfaction. The main factor here was the dominant and highly involved role of the client, who was able and willing to look for alternative options outside the construction industry and standard construction solutions. Since the successful office project, the offshore contractor has been involved in several other construction projects using a similar approach (Maas & Van Eekelen, 2004).

Figure 4: Construction and transport of The Bollard office building (pictures by courtesy of Mammoet and Grootint/Heerema)

5.2 Investigating application of aerospace production management concepts to construction

The aerospace industry has developed and changed quite rapidly. New concept have been developed and applied in the industry. Inversely, transferring "best practices" from the aerospace industry to other industries may be useful (Mathaisel & Comm, 2000). For instance, agile manufacturing has become common practice in aerospace increasing process robustness in the supply chain by creating a "common operating environment" (Phillips, 1999; Gunasekaran et al., 2002). Pushing suppliers' flexibility and responsiveness through first-tier level to sub-tier level has been making the aerospace supply chain lean, reduced variability and production risks, and centralised commodity management (Michaels, 1999). This has lead to applying ever more integrated buyer-supplier relationships in the supply chain (Graham & Ahmed, 2000), towards extended enterprise kind of corporate structures, and global "supply webs" as has been known from the automotive industry (Sehdev et al., 1995; Williams et al., 2002). Strict demand chain management and design for manufacture have lead to high levels of structural integration within the supply chain to resolve problems between design and manufacture of complex products and facilitate direct input of high-tech expertise in the aerospace industry. Current aerospace manufacture is therefore highly dependent on tiers of platform assembly and integral architectures where major subsystems (frame, shell, hydraulics, engines etc.) are supplies through relatively high number of closely integrated suppliers. Product technology complexity has increased heavily over the last years, which has invoked efforts to reduce production complexity and increase the level of product modularisation and production platform approach to reduce the complexity of supply chains, e.g. lowering transaction and production costs (Williams et al., 2002).

Graham (1999) observes characteristic differences in project structure and materials and information handling between aerospace and construction. Production in aerospace appears to be more repetitive and production management is more formal. Green et al.(2002) argue that the different industrial contexts, competition, technology level and relationship with government, has influenced the nature of management practices in both industries. Therefore the transfer of management concepts from one industry to the other may be difficult or

infeasible. Prime contracting is identified as a path that may increase the role of supply chain management in construction, and collaborative relations between contractors and suppliers for delivery of integrated services as seen in the aerospace industry (Green et al., 2002). In addition, construction could be improved by using basic concepts and principles from aerospace, including uniform and integrated approaches to design and outsourcing, integrated supply chain design systems, ICT systems for virtual reality and design evaluation, and involvement of contractors and suppliers in product development (Hazewinkel, 2005).

6. TRANSFER OF MANAGEMENT CONCEPTS BETWEEN INDUSTRIES: LEARNING FROM OTHER INDUSTRIES

Although industries are always different, applying management concepts, engineering and production techniques and logistics from other industries to construction have indicated and demonstrated to be possible and give opportunities for improvement of construction practice. Many industries are observed to be relatively more advanced than construction in terms of project, production and supply chain management. As a consequence, one could say there are opportunities and a need to learn from other industries. Also on many other areas, construction could learn from other industries, for instance in terms of life cycle costing techniques originating from the defence industry (Garnett & Owen, 1995). In all cases, concepts need to be transferred into a construction context, which may be more difficult for some concept, than others.

Green et al.(2004) warn against to be "over-simplistic" in the approach for learning from other industries and not disregard the embedded and contextual nature of managerial concepts. They consider learning as 'sharing between business sectors as an essential source of innovation. Comparisons between the aerospace and construction sectors are especially useful because they are so different in terms of their institutional context, structure and technological intensity. This helps to explain how managerial practices are mediated by context'.

If construction would move away from mere project focus on time and budgets, and assume higher levels and speed of innovation, product development and customer focus as seen in other more advanced industries, construction must assume a more structured approach through projects and supply chains. This implies adopting more integrated and strategic procurement by clients, and applying more integrated and sustainable supply chain strategies by contractors and suppliers. When it comes to learning from other industries with regards to supply chain management, the consequences may be that construction needs to shift to more integrated and centrally controlled supply chains, reduced levels of autonomy among supply chain partners, more product development and project-independent approaches to production instead of mere classical project delivery (Voordijk & Vrijhoef, 2003).

7. DISCUSSION AND CONCLUSION

Industry characteristics do strongly influence performance and performance drivers of firms in different industries (Hamblin & Iyer, 1996). The characteristics of construction as a project-based industry and current project management practices in construction have often been pointed out to be the cause of low performance levels compared to other industries. Resolving the negative effects caused by the peculiarities of construction foremost must be achieved by altering the production and project management practice in construction. Since this kind of improvement is aimed at the improvement of current practice, further improvements may be needed aiming at the structural and cultural levels of the industry, and introducing new management principles and business concepts. These principles and

concepts may well be originated in other industries, and transferred and translated into a construction context. It has been shown that the transfer of these principles and concepts may be integrated, applying to the transfer of a relatively complete principle or concept, or partial, applying to the transfer of separate lessons based on their underlying principles from other industries to construction. Both incremental innovations and more radical changes and innovation to construction practice have been observed.

In most cases comparisons between construction and other industries have referred to other technology-driven industries, like automotive, and often to technology-driven project-based industries, like shipbuilding. However, in this paper, some initial comparisons have been made with non-technological sectors, including project and non-project industries. It may be an interesting exercise to further investigate this path to find unconventional directions for improvement of construction practice and the construction industry in general.

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