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SUPPLY CHAIN MANAGEMENT IN CONSTRUCTION FROM A PRODUCTION THEORY PERSPECTIVE

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ABSTRACT

Production management in construction is moving away from conventional construction management. The correctives to this model have been explicitly or implicitly based on flow and value principles. Supply Chain Management (SCM) is often presented as suitable for efficient management of construction production, but its successful implementation in the industry remains limited, particularly at the lower tiers of the construction supply chain. This paper takes a closer look at SCM – an analysis from the production perspective might help to create a better understanding of the concept and the key principles presented could be prescriptive in the further development of SCM in construction.

KEYWORDS

Construction management, supply chain management, production theory, key principles.

INTRODUCTION

Despite the successful examples of Supply Chain Management (SCM) initiatives at the higher tiers of the construction supply chain, relationships at the lower tiers seem to remain traditional and the SC Maturity of construction firms continues to be low (Broft et al., 2016). The quality of a main contractor-supplier relationship affects the main contractors' ability to perform on projects (Kale &Arditi, 2001). The increasing percentage of project turnover which is spent on buying goods and services provides opportunities for contractor-supplier collaboration, and emphasises the importance and significance of managing suppliers (Bemelmans et al., 2012). Main contractors are willing to develop closer relationships, but implementing SCM seems a long-term, complex process and requires a certain level of understanding and therefore learning throughout the supply chain (Broft et al., 2016). In the last decades, various supply chain concepts have emerged in parallel in generic theory and manufacturing practice – all

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highly related, leading to a high ambiguity between the definitions of the different concepts and reflecting the cross-functional nature of SCM (Ellram& Cooper, 2014).

This paper takes a closer look at SCM as an alternative for efficient management of construction production. An analysis from the production perspective might help to create a better understanding of the concept, which is seen as a corrective to the conventional construction management model, dominated by the transformation concept (Koskela, 2000) – discussion exists whether SCM is based on flow or value principles.

CONSTRUCTION FROM A PRODUCTION PERSPECTIVE

"*Production is the action of making or manufacturing from components or raw materials, or the process of being so manufactured*" (Oxford Dictionaries, 2018).

Production has three kinds of goals – besides the general goal of getting intended products produced, there are internal goals related to the characteristics of the production itself (i.e. cost minimisation and level of utilisation) and external goals related to the needs of the customer (i.e. quality, dependability and flexibility) (Koskela, 1999). Production theory and practice has sprung from thinking about repetitive manufacturing – it has essentially been theory about making (Ballard, 2005). Three different conceptualisations of production have been used in practice and conceptually advanced in the 20th century (Table 1) – each of them captures an intrinsic phenomenon of production (Koskela, 2000).

Table 1: Transformation, flow and value views on production (Koskela, 2000)

	Transformation view	**Flow view**	**Value view**
Conceptualisation of production	As a transformation of inputs into outputs	As a flow of material, composed of inspection, moving, waiting and trans-formation	As a process where value for the customer is created through fulfilment of his requirements
Main principles	Getting production realised efficiently	Elimination of waste (non-value-adding activities)	Elimination of value loss

THE PRODUCTION-RELATED CHARACTERISTICS OF CONSTRUCTION

In construction, a supply chain shows the following production-related characteristics:

- Converging logistics to a *common and fixed point* in the supply chain: the construction site where the 'construction factory' is located (Luhtala et al., 1994);
- *Temporary and non-repetitive*, or in other words, one-off construction projects that are produced through repeated reconfiguration of project organisations (Vrijhoef & Koskela, 2000) – construction is prototype production;
- *Multiple and concurrent* projects (Souza de Souza, 2015);
- A number of studies have linked construction with the characteristics of the *Engineer-to-order* (ETO) production strategy – ETO-projects are described as

having high levels of customisation and typically managed on a project basis (Gosling et al., 2012).

- Construction is mainly based on two types of processes: *small batch process and job process* (Krajewski et al., 2007);
- One location can be worked on by *several work stations at the same time* and work is carried out in *suboptimal conditions*, with lessened productivity (Koskela, 1999).

THE PECULIARITIES OF CONSTRUCTION

The characteristics of construction are often seen as peculiarities of the industry, preventing the attainment of flows as efficient as in manufacturing (Koskela, 1999).These peculiarities are considered to differentiate between project-based industries and repetitive manufacturing, where SCM was born (Elfving& Ballard, in press). Despite the fact that other types of production also possess one or several of these characteristics, it is the combination of properties that defines construction 'peculiar' (Ballard & Howell, 1998) – construction objects possess two characteristics which together uniquely define them: (1) they belong to the category "fixed position manufacturing", and (2) they are rooted in place. The objects of fixed position manufacturing are wholes assembled from parts. In the assembly process, the parts become too large to move through assembly stations, so the stations move through the emerging wholes, adding pieces as they move. Some degree of site production, at minimum the final assembly, is a necessary aspect of construction. This rootedness-in-place brings with it uncertainty and differentiation (Ballard & Howell, 1998).

The organisation of production and the supply chains is strongly adapted to these basic characteristics (Koskela, 2000; Broft, 2017).

CONSTRUCTION MANAGEMENT FROM A PRODUCTION PERSPECTIVE

The construction industry, both theoretically and in practice, has been dominated by the transformation concept (Koskela, 2000) with three main features: (1) a sequential method of project realisation where design and construction are separated, (2) procurement through bidding; and, (3) segmented control with institutionalised roles and division of work. This conventional model was criticised for its centralised and formal management, as this does not recognise the uncertainty of and interdependence between the operations of the construction process (Tavistock Institute, 1966). The correctives to the conventional model have been explicitly or implicitly based on flow (i.e. Design-Build and lean construction) and value principles (i.e. quality management). One of these correctives, SCM, can be seen as an alternative for realising efficient construction management.

PRODUCTION THEORY: SCM IN CONSTRUCTION

In construction, SCM is often seen as a project-specific approach (Green et al., 2005). Main contractors have a central position in the management of supply chains (Pryke, 2009) – it is believed that main contractors have more influence on the organisation of the

project and on the performance and quality of the work of its suppliers. However, implementation of SCM by main contractors is relatively slow (Green et al., 2005). This section analyses the concept from the different production theory perspectives.

FROM A TRANSFORMATION PERSPECTIVE

Production can be seen as a transformation of inputs into outputs, or in other words, as the transformation of one set of resources into a second set (Grubbström, 1995). The total transformation process can be decomposed into subprocesses, which are smaller, more manageable transformation processes (Koskela, 2000) – production management equates to carrying out these 'tasks' as efficiently as possible. Every process exists of any activity or group of activities that takes one of more inputs, transforms them, and provides one or more outputs to its customers (Krajewski et al., 2007).

As a consequence of the uncertainty faced by main contractors in obtaining continuous work and the need to accommodate the different, increasingly specialised and complex, requirements of each project (Tam et al., 2011), most of the subprocesses known in a construction supply chain are outsourced or subcontracted to specialist organisations, suppliers (Broft et al., 2016), focusing on the production of a specific subprocess (Figure 1).As a result, the main contractor, the principal construction organisation that manages a construction project, executes only a small part of the product by its own personnel and its own production facilities (Dubois & Gadde, 2000).

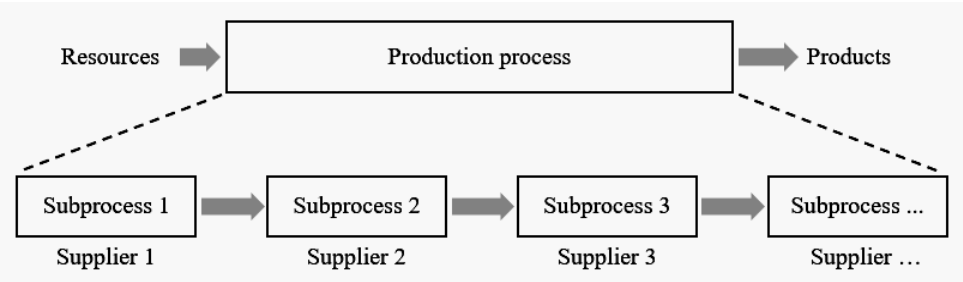

Figure 1: Decomposition of a production process in a supply chain (adapted from Koskela, 2000; p.42)

From a transformation perspective, subprocesses are considered independent from each other and subsequently, the cost of the total process can be minimised by minimising the cost of each subprocess. In order to get every new construction project executed to the lowest possible cost (Eriksson, 2015), competitive pricing is promoted through procurement strategies often pursued by clients, featuring purchasing transactions (Gadde & Dubois, 2010) and favouring the lowest bidder. Contractually, main contractors are responsible for the construction of projects, but they rely on suppliers to execute the works (Clarke & Herrmann, 2004) – they do this to reduce their overhead and operating costs, improve efficiency, and achieve a more economic delivery of projects (Arditi & Chotibhongs, 2005). As part of task management, all these subprocesses (or effectively suppliers), and the costs involved need to be managed. SCM offers an alternative way for this production management, involving the control and optimisation of decomposed and subcontracted activities, where suppliers are invited to focus on the efficiency of their subprocess (through, i.e., standardisation and

prefabrication) and to eliminate unnecessary costs (with the help of the production manager).

Here, a supply chain is defined as a set of three or more entities (organisations or individuals) directly involved in the upstream and downstream focus of products, services, finances and/or information from a to a customer (and in reverse) (Mentzer et al., 2001). SCM, using a process orientation (Ellram & Cooper, 2014), considers the supply chain as a means for linking structured activities designed to produce an output for a particular customer or market, and a means to improve and/or coordinate processes. It looks at activities, where activities could be seen as a single element of a process (Burgess et al., 2006), or processes versus the relationships in supply chains. As a result of the fragmentation and prevalent competitive tendering, construction supply chains are disjointed (Eriksson, 2015). This means that current construction practice, where the relationship with suppliers is considered to be exclusively transactional, with no relational component (Elfving & Ballard, in press), fits the transformation perspective. SCM from the transformation perspective considers these relationships. As opposed to transaction cost economics (TCE) that treats each transaction separately (make-or-buy), SCM includes the systems benefits of organising clusters of related transactions as supply chains are introduced – related transactions are grouped and managed as chains (Williamson, 2008). SCM could then involve elements such as the creation of a more permanent production process through long-term relationships with suppliers. This offers alternative ways of minimising (transaction) costs (Pasquire et al., 2015).

FROM A FLOW PERSPECTIVE

When production is depicted as a flow of material, the flow consists of four stages: processing, inspection, moving and waiting (Gilbreth & Gilbreth, 1922). These transformation and non-transformation activities both consume time from the point of view of the product – the amount of time consumed by the total transformation and its parts or subprocesses plays an important role in the flow conceptualisation (Koskela, 2000). For this reason, production management tries to shorten the total time by eliminating non-value adding phenomena or waste from the production process (Shingo, 1988). In other words, production management involves the management of flow. It minimises the share of non-transformation stages of the production flow, especially by reducing variability as variability increases the lead time. There are two types of variability in flows of production: process-time variability which refers to the time required to process a task at one workstation, and flow variability meaning the variability of the arrival of jobs to a single workstation (Hopp & Spearman, 1996).

From a flow perspective, the object of SCM is "to integrate and manage the sourcing, flow and control of materials using a total system perspective across multiple functions and multiple tiers of suppliers" (Mentzer et al., 2001). A supply chain, encompassing all the subprocesses (as explained and visualised in Section 3.1), is conceptualised as a production flow (rather than a series of transactions or contracts) – it covers the flow of goods from the different suppliers through manufacturing and distribution chains to the end user (Christopher, 2005).

A manufacturing system, which involves the flow of material through a plant – is an objective-oriented network of processes through which entities (the parts to be manufactured) flow (Hopp & Spearman, 1996). Besides the flow of materials, construction knows two other flows: location flow and assembly flow, which are related to the characteristics of construction as described in Section 2.1 and 2.2: Production in construction is of assembly-type, where different material flows are connected to the end product on-site. Due to the size of the product of construction, an intermediate workflow arises where all installation locations proceed through the installation work station (Koskela, 2000). Whilst conventional construction management focuses on the project, SCM emphasises the product and the tasks or subprocesses organised around this product as a network – the realisation of tasks heavily depends on flows, and the progress of flows in turn is dependent on the realisation of tasks (Koskela, 1999). Coordination between subprocesses or supply chain partners is important in order to boost total process efficiency and effectiveness across members of the supply chain (Lambert et al., 1998).

SCM from the flow perspective acknowledges the interdependency between subprocesses and includes integration. The current approach in construction might still be sequential, but SCM in construction should be seen as the management of a network of interconnected organisations that are involved in the different processes and activities that produce products and services to the customer (Dainty et al., 2001; Christopher, 2005). Owing to the still disconnected processes and the large number of suppliers, main contractors are needed to coordinate operations to provide focus and integration of the varied parts (Akintan & Morledge, 2013): SCM is "the task of integrating organisational units along a supply chain and coordinating materials, information and financial flows in order to fulfil customer demand with the aim of improving competitiveness of a supply chain as a whole" (Stadler, 2000).This integration between subprocesses focuses, from the flow perspective, on the overall efficiency of the entire supply chain, through the use of important flow-related principles – the reduction of the lead time of the product through the elimination of waste within the overall production process and the reduction of variability(Berliner & Brimson, 1988; Koskela, 2000). It equals to the synchronisation of a firm's processes with those of its suppliers and customers to match the flow of materials, services, and information with customer demand (Krajewski et al., 2007).

FROM A VALUE PERSPECTIVE

Production can also be seen as a means for the fulfilment of the customer needs. Production management equates to translating these needs accurately into a design solution and then producing products that conform to the specified design. This concept reflects the importance of a focus on value. In construction, the attitude tends to be oriented towards conformance to contractual specifications rather than gaining additional financial benefits or competitive strength from quality improvement (Vrijhoef, 2011). As a result, construction seems oriented more towards production and getting the work done on time and within budget (Lai & Cheng, 2003) – the project success measure is cost, and completing the project by the scheduled date is generally the most important scheduling objective (Tukel & Rom, 1998).

SCM involves the integration of key business processes from the end user through original suppliers that provide products, services, and information that add value for customers and other stakeholders (Lambert et al., 1998).Value creation has become a function of the network of iterative and transient relationships between actors that are connected – construction projects are essentially about the creation of new value in society, delivered by a network of relationships between firms that make up the project coalition (Pryke, 2009).This value includes time, costs and quality. In SCM, all supply chain actors need to be able to make a full contribution to ensure that the client's needs are fulfilled and that value creation is maximised (Broft et al., 2016). This implies a collaborative customer focus and a higher quality of the delivery of each subprocess. SCM also encourages integrated project delivery (IPD) or common product development as suppliers are involved early in the process and play an important role in the design stage, invited to work on target cost (Anderson, 2006) and to contribute to pre-designed solutions. Target costing is an important aspect of SCM – it is an effective inter-organisational management technique that has been used in manufacturing toachieve cost predictability during new product development (Zimina et al., 2012) in a supply chain. It helps to ensure that new products and services meet market-determined prices and provide financial returns (Cooper &Kaplan, 1999).The value perspective also focuses on SCM's main objective to enhance mutual competitive advantage (Pryke, 2009).

SCM IN CONSTRUCTION FROM A TFV-PERSPECTIVE

SCM is considered a way of thinking about management and processes, which includes improved relationships, integrated processes and increased customer focus (Pryke, 2009). Integration (or interdependency) and value creation – important aspects of the F- and V-conceptualisations of the production theory – seem to be essential in SCM. Table 2represents the characteristics of SCM in construction from each production perspective, following from Section 3.1, 3.2 and 3.3. The table is descriptive – it decomposes SCM to its constituents and presents them as key principles.

Table 2: The characteristics of SCM in construction from a TFV-perspective

View on production	**Conceptualisation of SCM**	**Keyprinciples**
Common toall views	Long-term collaborations between supply chain actors to ensure a project-exceeding focus and to create a more permanent organisation.	▪ Long-term collaboration with suppliers.
Transformation	Managing all subprocesses, subcontracted to different suppliers, and logistics needed to perform a production process. Relationships between subprocesses are acknowledged, but remain transactional.	▪ Clusters of related transactions that are managed as chains; ▪ Non-temporary organisation; ▪ Alternative ways for the minimisation of transaction costs.
Flow	A supply chain, encompassing all	▪ Focus on overall efficiency;

	the subprocesses is conceptualised as a production flow. Coordination between subprocesses is important in order to boost total process efficiency and effectiveness across members of the supply chain. This involves the acknowledgement of interdependencies between subprocesses, and includes integration. This integration between subprocesses focuses on the overall efficiency of the entire supply chain.	▪ Lead time reduction through the elimination of waste and the reduction of variability; ▪ Product-focus (including the subprocesses organised around this product).
Value	Ensuring that the client's needs are fulfilled and that value creation is maximised – all supply chain actors need to be able to make a full contribution. This implies a collaborative customer focus and a higher quality of each delivered subprocess.	▪ Fulfilment of customer requirements for the product regarding time, cost and quality; ▪ A higher quality of each delivered sub-product; ▪ Collaborative customer focus; ▪ Common product development; ▪ Supplier prequalification and early supplier involvement; ▪ Mutual competitive advantage.

CONCLUSION

Production management in construction is moving away from conventional construction management. The correctives to this model have been explicitly or implicitly based on flow and value principles. SCM is often presented as suitable for efficient management of construction production. Its successful implementation in the industry, however, remains limited to the improvement of logistics and inventory, whereas in some industries SCM has become a central strategy, dealing with total business excellence.

This paper presents an analysis of SCM in construction from a production perspective. Important aspects of the F- and V-conceptualisations of the production theory have already been implicitly acknowledged in SCM, however, this paper provides the reader with a more descriptive and explicit conceptualisation of SCM from each production perspective and reflects the difference between each view on these conceptualisations.

Despite that all three SCM conceptualisations include long-term collaborations with suppliers, clustering subprocesses around a supply chain, each view on production emphasises a different aspect of SCM. Where transformation focuses on the transactional relationship between subprocesses (or in other words, suppliers) and focuses on cost minimisation accordingly, flow acknowledges the interdependency through the integration of processes and the creation of relationships, and value acknowledges the delivery of quality as a result of each subprocess. The differences have been presented in

Section 3.4 – Table 2 also describes the associated key principles. In this way, the paper creates a better understanding of the SCM concept and suggests that for SCM to succeed in the best possible manner, all three views need to be considered and promoted. This understanding could be used prescriptively in the further development of SCM in construction, and added clarity of the concept might subsequently offer opportunities for successful implementation of SCM at the lower tiers of the construction supply chain.

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