

# PRACTICES FOR DESIGNING AND IMPROVING CONSTRUCTION SUPPLY CHAIN MANAGEMENT

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## ABSTRACT

This paper aims at proposing a set of practices for designing and improving construction supply chain management. Such practices were developed based on broad literature review and on interviews conducted in late 2012 and early 2013.

Construction companies face difficulties in coordinating supply chain management towards value generation. Results indicate that construction companies building unique projects require a specific approach for managing their supply chains. Outcomes also show that the proposition of contextualized practices facilitates supply chain management in such complex environment, and enables enhanced project delivery. Even though this is a theoretical study, the paper's findings are useful to both practitioners and academic researchers.

## KEYWORDS

Construction, Supply chain management, Practices, Design, Improvement.

## INTRODUCTION

Construction companies have become complex. Such complexity has been also extended to their boundaries, and therefore to their supply chains. Special, unique, and one-of-a-kind are expressions used to determine the nature of some construction developments, especially those related to industrial, commercial, and infrastructure projects. Gosling et al. (2012) defined Engineer to Order (ETO) projects by having high levels of customization, typically managed on a project basis, and directed to construction, capital goods, and shipbuilding sectors. Hicks et al. (2000) stated that there is limited supply chain research in the low-volume ETO segment, even though supply chain management has been referred as a strategic issue for companies adopting such production strategy. Olhager (2003) presented the relation between the Order Penetration Point (OPP), also referred as Customer Order Decoupling Point (CODP), and the different production strategies. According to the OPP proposition, ETO construction projects usually have their OPP positioned early at the design stage (Olhager 2003; Gosling et al. 2012) as shown in Figure 1. In addition, ETO construction projects have also been characterized by requiring multidisciplinary design and fabrication skills from their supply chains (Eastman et al. 2011).

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The OPP represents the point in the value chain in which the product is linked to a determined customer order (Olhager 2003). An important implication from the OPP is the division of the diverse production activities according to their orientation. Stages upstream of the OPP are forecast-driven and stages downstream of the OPP are customer-driven (Olhager 2003). In this sense, ETO construction projects have the OPP before or at the Design stage, and therefore all subsequent activities are based on specifications and requirements from the customer.

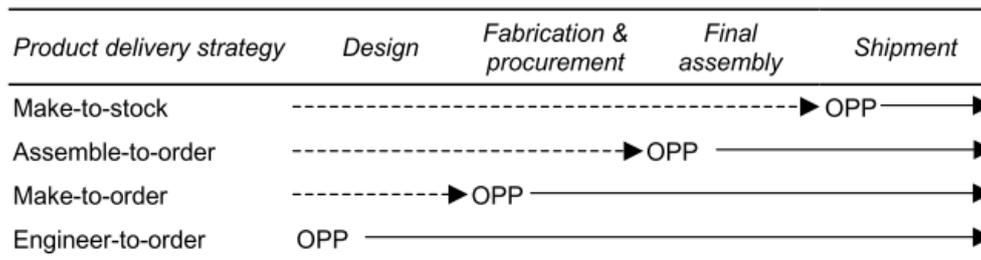


Figure 1: OPP, production strategies, and production activities (Olhager 2003)

The investigations regarding Construction Supply Chain Management (CSCM) have evolved over the last years towards a better understanding of its intrinsic characteristics. High levels of customization, low volumes of production, reduced repeatability of activities, temporary-based developments, and early OPP are the key issues that influence CSCM (Hicks et al. 2000; Gosling et al. 2012). Such issues produce several problems at the interfaces of CSCM and they were listed in Vrijhoef & Koskela (2000): incomplete order specifications, long order processing time, lack of trust, poor synchronism throughout supply chain, last minute changes, among others.

In order to address the problems of CSCM in a structured way, Souza & Koskela (2012) stated that CSCM should be studied by using the production system perspective. Early developments of Supply Chain Management (SCM) from the manufacturing sector have indicated that although SCM is a network of activities it should be analysed via process-oriented frameworks (Stewart 1997; M. C. Cooper, Lambert, et al. 1997). The analogy between the production process perspective and CSCM proposed by Souza & Koskela (2012) splits the process into three interrelated stages: design, operation, and improvement as shown in Figure 2. In this paper, design and improvement are the focus of the discussion based on the idea that both stages produce impacts in operation. In addition, current research of SCM has focused on the operational stage and there is a lack of research for designing and improving supply chains.

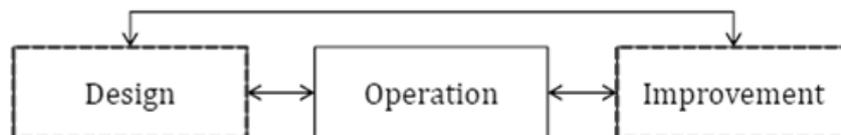


Figure 2: CSCM process and its stages (adapted from Souza & Koskela 2012)

The aim of this paper is to present a set of practices for designing and improving construction supply chain management. For addressing such purpose, a literature review and a set of interviews have been conducted with academics and practitioners from the construction sector. Outputs from this research justified the proposition of a contextualized framework for managing construction supply chains, and supported the introduction of a set of practices for designing and improving CSCM.

This paper has three further sections. The second section presents the research methodology developed in this study. The third section introduces the set of proposed practices and discusses their implications for the construction sector. Finally, a conclusion section includes research limitations and a brief description of future work.

## **RESEARCH METHODOLOGY**

The research methodology proposed in this study is divided into four sequential and interdependent steps. Such steps have been defined in a chronological basis and they have been significantly helpful in order to conduct this study. Also, the development of this research has been based on interviews conducted in person or via videoconference software.

First, the participants have been selected according to their professional and academic background. This research has interviewed participants from Brazil and UK in order to gather different points of view from two business cultures. The criteria for selecting the participants have been based on their previous experience in construction projects, understanding about construction supply chains, and level of education. The interviews were conducted between late 2012 and early 2013 and each interview took 60 minutes. The purpose of the interviews was not to generalize theory from them. On the contrary, the interviews were used for collecting perceptions from the participants and put them together with findings from the literature. The participants have been formally invited in order to take part in this research. A total of five participants have been interviewed, in which two participants were from two major construction companies and three participants were from three different universities. The names of the participants, companies, and educational institutions were not disclosed. For demographic purposes, the background and the number of years of experience of each participant is presented in Table 1.

Table 1: Interviewee's background and experience

<b>Interviewee</b>	<b>Professional Title</b>	<b>Background</b>	<b>Country</b>	<b>Years of experience</b>
Interviewee #1	Commercial Manager	BSc in Civil Engineering	Brazil	> 15
Interviewee #2	Professor	PhD in Civil Engineering	Brazil	> 15
Interviewee #3	Contract Manager	BSc in Civil Engineering	Brazil	> 10
Interviewee #4	Senior Lecturer	PhD in Operations Management	United Kingdom	> 10
Interviewee #5	Lecturer	PhD in Operations Management	United Kingdom	> 5

Second, a semi-structured questionnaire has been prepared in order to support the interview process. The interviews have been based on the proposed questionnaire and questions have aimed at exposing what initiatives, practices, guidelines, and issues are relevant for managing construction supply chains. In order to introduce the discussion and provide a justification for this research, the following question has been asked to the interviewees “*Is a contextualized set of practices for construction supply chain management necessary?*”. The word contextualized has been used in order to define that such practices must address the specificities from a context, in this case ETO construction companies.

Third, data collected from the interviews has been transcribed and categorized. Data categorization has been deployed via two foci. The primary aims at finding the strategic relevance and background for developing a contextualized set of practices for construction supply chain management. The secondary endeavours to describe the relevant elements pointed by the interviewees for designing and improving construction supply chains. References from operations and construction management literature have been used for supporting the practices.

Finally, a discussion regarding the applicability of the practices and their interrelations is presented. Also, directions for future research and implications from this study are outlined in order to support further developments.

## **PRACTICES FOR DESIGNING CONSTRUCTION SUPPLY CHAIN MANAGEMENT**

The practices below have been related to construction supply chain management design:

- a) **Customization of SCM design:** ETO construction companies need to customize their supply chain management design and do not adopt standard solutions. This argument has been presented by the interviewees due to the level of strategic influence of SCM in the company’s strategy. It has been reported that supply chain management should be aligned with the business characteristics of the product and therefore of the company (Fisher 1997).
- b) **Positioning of the decoupling point:** in the ETO construction projects the decoupling point is positioned at the early stages of production activities, namely design stage (Olhager 2003). Such decoupling point position suggests a high level of customer involvement and therefore more flexibility of the production process.
- c) **Supply chain mapping:** ETO construction companies have many concurrent projects in their portfolio. Such projects have similarities and differences in their intrinsic characteristics as they are one-of-a-kind. The similarities of the projects are related to top-consumed materials (i.e. rebar, cement, concrete) and company’s resources (i.e. IT software, quality guidelines, and shared-services staff) that they demand. Nevertheless, the projects present their specificities also in terms of materials (i.e. ETO components such as structural steel, precast concrete structures, and MEP systems) and company’s resources (i.e. specialized staff, health and safety support, managerial support). It is recommended to map the supply chain (M. C. Cooper, Ellram, et al. 1997)

and eliminate waste in the process by using Value Stream Mapping (Rother & Shook 1999)

- d) **Enterprise-project interface management:** as 2 different levels of management have been proposed (enterprise level and project level), the interface between them becomes a critical success factor (Ayers 2004). In this sense, internal integration efforts should be prioritized in order to improve project delivery and company's performance.
- e) **Early supplier involvement:** ESI has been pointed by the interviewees as a useful technique for construction supply chain management. Such technique has been alternatively named as pre-construction and has been widely discussed in the literature (McIvor 2004; Dowlatshahi 1998). Interviewees have reported that ESI has reduced conflicts throughout the projects, reduced uncertainty and variability, and increased customer satisfaction. Also, the interviewees have pointed that ESI requires a specific policy to manage the level of supplier involvement.
- f) **Governance management:** Interviewees have stated that there is a lack of supply chain governance by the construction companies and this has led to structural fragmentation of their supply chains. Also, the interviewees have attributed to power dynamics a large influence in integration, co-ordination, and collaboration within the SCM environment. Previous research have addressed the relevance of governance in supply chain (Roehrich & Lewis 2010; Pietroforte 1997).
- g) **Supplier base management:** interviewees have acknowledged the importance of reducing supplier base and invest in long-term relationships as a policy for SCM as discussed by M. J. Schniederjans et al. (2010). Nevertheless, interviewees have pointed one-of-a-kind projects have special requirements and may need suppliers never contracted by the ETO construction company. In addition, this study has found that new suppliers can also be necessary due to the location of the project and the necessity for local suppliers.
- h) **Risk management:** risk management in construction supply chain management has been associated with supplier's dependency of the focal company. First, once a project has been established it has its delivery completely dependent on the performance of the suppliers. Second, there is the case in which suppliers have high levels of dependency of the ETO construction companies. Such suppliers might be affected by economic fluctuations that eventually impacts project's bidding process. Risk management has been studied combined with early supplier involvement by (Zsidisin & Smith 2005).
- i) **Sustainability management:** interviewees have pointed sustainability as a strategic issue. Not only the direct green aspects have been mentioned (i.e. green policies and guidelines for packaging) but also the extent in which supply chains can be sustainable over the years in terms of their environmental impact in other supply chains (i.e. recycled packaging applied in the production of other materials) (Melnik et al. 2010).

- j) **Flexibility management:** this study has found flexibility as relevant competitive criteria for construction supply chain management (Gosling et al. 2012). It is opinion of the interviewees that ETO supply chains require flexible initiatives in its management in order to assure project delivery.

## **PRACTICES FOR IMPROVING CONSTRUCTION SUPPLY CHAIN MANAGEMENT**

The practices below have been related by the interviewees to construction supply chain management improvement:

- a) **Variability reduction:** this study has found variability as the first aspect to be improved in construction supply chain management. The interviewees have attributed to the long project's lead-times the major source of variability in construction projects. In addition, demand uncertainty has been pointed out as a significant cause of variability as well. Koskela (1992) has indicated variability reduction one of the most relevant principles for effectively implementing the lean production philosophy and eliminate waste.
- b) **Performance measurement:** a controversial relation between performance measurement and improvement has been pointed by the interviewees. On the one hand, they argued that performance measurement is essential for improvement. On the other hand, they pointed that usually suppliers cannot deliver pre-defined performance (in terms of quality, cost, and quality) and difficulties in measuring performance are amplified through the different tiers of their supply chains. Previous studies have highlighted the relevance for measuring performance in construction supply chains (Kagioglou et al. 2001; Souza & L. Koskela 2012).
- c) **Improvement prioritization:** deciding what should be improved is an issue for construction companies and their supply chain management processes. Categorization of problems and their prioritization was pointed as a crucial path for sustainable improvement process. The interviewees argued that a company must improve its supply chain in order to address the competitive priorities. Finally, this study has found that ABC classification<sup>3</sup> of the suppliers have been pointed as an upcoming initiative for prioritization of improvement efforts. Previous research have studied how to coordinate and prioritize efforts in supply chain management (Sharma & Bhagwat 2007; Verdecho et al. 2012).
- d) **Benchmarking and knowledge management:** learning with suppliers is important for improvement according to the interviewees. Such learning process must be based on two major approaches: benchmarking and knowledge management. Benchmarking has been experienced by the

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<sup>3</sup> ABC classification of suppliers is the definition of their strategic importance. Such importance ranks suppliers in three different levels: A, B, and C. Suppliers in level A are strategically important and require a close working relationship. Suppliers in level B are important but they do represent a high risk for the company. Finally, suppliers in level C are defined as non-critical and can be replaced by other options from the market (SAP, Supplier Portfolio Management).

interviewees in terms of best practices exchange and definition of targets for performance metrics. However, benchmarking has been pointed as a difficult technique to implement due to trust issues in information sharing in the supply chain environment (Malin 2006).

- e) **Supplier development:** supplier development has been associated with two initiatives organized by the focal company: training schemes and management consultancy (Handfield et al. 2000). The interviewees pointed that training schemes are very helpful in terms of improvement for suppliers, however they have stated they are hard to implement. On the other hand, they demonstrated a positive view of management consultancy support in order to improve supplier's performance. It is opinion of the interviewees that supplier development must be monitored via KPIs in order to link its outputs with the focal company results. Such KPIs must be managed constantly and they can be used as basis for supplier's feedback.
- f) **Communication management:** communication has been closely associated with improvement: the more communication with suppliers the better (Zsidisin & Smith 2005; Pietroforte 1997). It is the opinion of the interviewees that communication must be conducted via direct and indirect channels. The ERP (Enterprise Resource Planning) and EDI (Electronic Data Interchange) systems play an important role in terms of facilitating communication with suppliers. The interviewees have argued that suppliers respond satisfactorily to policies, guidelines, and requirements released via "official" communication channels rather than informal communication.
- g) **Simplification and standardization:** the more standardized process a company and its suppliers adopt the better according to the lean principles for eliminating waste (Koskela 1992). The interviewees pointed that it is responsibility of the construction company to establish templates to be used for supply chain management at the company and at the project level. Also, the interviewees argued that modularization (pre-assembly or pre-fabrication) of building components is a very helpful initiative towards improvement supported by mass customized projects.

## **DISCUSSION**

The proposition of a contextualized framework for construction supply chain management has been supported by the findings of this study. It is opinion of the interviewees that such framework should be positioned at the strategic level, dealing with design and improvement issues. In their view supply chain management is "top level" and must not address operational activities.

This study has found that there is an established need for a contextualized framework for construction supply chain management: there is a lack of research in this sense. Also, it has found the underpinnings of construction supply chain management must be designed for value generation. It is opinion of the interviewees that all policies, guidelines, and activities adopted by the focal company (Lambert et al. 1998; M. C. Cooper, Lambert, et al. 1997) compose the "modus-operandi" for its supply chain.

By revisiting design and improvement, it is convenient to relate them with the argument of the interviewees: supply chain management is top level. Usually companies focus their actions at the operational stages (i.e. more efforts in designing and improving purchasing rather than procurement) and this is not the focus of this paper.

Initiatives have been developed towards the development of frameworks for designing and improving construction supply chain management supported by lean-agile theories (Lu et al. 2011; Naim & Barlow 2003) and further research in this direction has been recommended (Barlow et al. 2003). The proposition of a set of practices supporting supply chain management design and improvement consolidates the basis to be adopted by ETO construction companies.

On the one hand, a set of ten practices has been defined from the findings of this study for construction supply chain management design. Such elements comprise key issues for an effective construction supply chain management design. Companies adopting ETO production strategy within the construction sector should adapt such practices and develop an internal framework considering early supplier involvement, risk management, and flexibility, among others. The development of company's strategy also should be linked with these ten proposed practices in order to promote a robust and comprehensive approach towards market competition.

On the other hand, a set of seven practices has been obtained as findings from this study for construction supply chain management improvement. Top level departments of the ETO construction companies should look into supplier's development, standardization, and variability reduction in order to propose strong action plans and improvement projects internally and in the supply chain environment.

It is worth mentioning that set of practices for construction supply chain management provides a major benefit for construction companies: to focus their efforts. The definition of practices facilitates the organization of work at the enterprise and at the project level, and might lead to increasing performance. Thus, the value of a framework can be measured in terms of its impact in supporting decision making and processes operations.

## **CONCLUSION**

The research in construction supply chain management proves to be necessary in order to provide guidelines for top level management in construction companies. The paper concludes that there is room for in depth study of the two stages (design and improvement) in the context of ETO construction companies. The proposition of a set of practices for supporting construction supply chain design and improvement establishes robust guidelines for top management, and such guidelines can be adapted in the individual context of the companies. Thus, this paper brings contributions for both academics and practitioners.

Future studies can be used to check, add, and validate the practices proposed for designing and improving construction supply chain management. In addition, further developments can establish the correlation between practices of design and improvement in a matrix, determining which elements are only at the project, enterprise, and both project and company levels.

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## **REFERENCES**

- Ayers, J.B., 2004. *Supply Chain Project Management*, St. Lucie Press.
- Barlow, J. et al., 2003. Choice and delivery in housebuilding: lessons from Japan for UK housebuilders. *Building Research & Information*, 31(2), pp.134–145.
- Cooper, M.C., Ellram, L.M., et al., 1997. Meshing multiple alliances. *Journal of Business Logistics*, 18(1), pp.67–89.
- Cooper, M.C., Lambert, D.M. & Pagh, J.D., 1997. Supply chain management: more than a new name for logistics. *International Journal of Logistics Management*, 8(1), pp.1–14.
- Dowlatshahi, S., 1998. Implementing early supplier involvement: a conceptual framework. *International Journal of Operations & Production Management*, 18(2), pp.143–167.
- Eastman, C. et al., 2011. *BIM Handbook*, Wiley.
- Fisher, M.L., 1997. What is the right supply chain for your product? *Harvard Business Review*, pp.105–116.
- Gosling, J., Naim, M.M. & Towill, D.R., 2012. A supply chain flexibility framework for engineer-to-order systems. *Production Planning & Control*.
- Handfield, R.B. et al., 2000. Avoid the pitfalls in supplier development. *MIT - Sloan Management Review*, pp.37–49.
- Hicks, C., McGovern, T. & Earl, C.F., 2000. Supply chain management: a strategic issue in engineer to order manufacturing. *International Journal of Production Economics*, 65(2), pp.179–190.
- Kagioglou, M., Cooper, R. & Aouad, G., 2001. Performance management in construction: a conceptual framework. *Construction Management and Economics*, 19(1), pp.85–95.
- Koskela, Lauri, 1992. Application of the new production philosophy to construction, Lambert, D.M., Cooper, M.C. & Pagh, J.D., 1998. Supply chain management: implementation issues and research opportunities. *International Journal of Logistics Management*, 9(2), pp.1–20.
- Lu, W., Olofsson, T. & Stehn, L., 2011. A lean-agile model of homebuilders' production systems. *Construction Management and Economics*, 29(1), pp.25–35.
- Malin, J., 2006. Knowing the SCOR: using business metrics to gain measurable improvements. *Healthcare Financial Management*, 60(7), pp.54–59.
- McIvor, R., 2004. Early supplier involvement in the design process: lessons from the electronics industry. *OMEGA - The International Journal of Management Science*, 32(3), pp.179–199.
- Melnyk, S.A. et al., 2010. Outcome-driven supply chains. *MIT - Sloan Management Review*, (51221), pp.33–38.
- Naim, M.M. & Barlow, J., 2003. An innovative supply chain strategy for customized housing. *Construction Management and Economics*, 21(6), pp.593–602.
- Olhager, J., 2003. Strategic positioning of the order penetration point. *International Journal of Production Economics*, 85(3), pp.319–329.

- Pietroforte, R., 1997. Communication and governance in the building process. *Construction Management and Economics*, 15(1), pp.71–82.
- Roehrich, J.K. & Lewis, M.A., 2010. Towards a model of governance in complex (product-service) inter-organizational systems. *Construction Management and Economics*, 28(11), pp.1155–1164.
- Rother, M. & Shook, J., 1999. *Learning to See*,
- Schniederjans, M.J., Schniederjans, D.G. & Schniederjans, A.M., 2010. *Topics in lean supply chain management*, Singapore: World Scientific.
- Sharma, M.K. & Bhagwat, R., 2007. An integrated BSC-AHP approach for supply chain management evaluation. *Measuring Business Excellence*, 11(3), pp.57–68.
- Souza, D.V.S. & Koskela, L., 2012. On improvement in construction supply chain management. In *Proceedings for the 20th Annual Conference of the International Group for Lean Construction*.
- Stewart, G., 1997. Supply-chain operations reference model (SCOR): the first cross-industry framework for integrated supply-chain management. *Logistics Information Management*, 10(2), pp.62–67.
- Verdecho, M. et al., 2012. A multi-criteria approach for managing inter-enterprise collaborative relationships. *OMEGA - The International Journal of Management Science*, 40(3), pp.249–263.
- Vrijhoef, R. & Koskela, L., 2000. The four roles of supply chain management in construction. *European Journal of Purchasing & Supply Management*, 6(3-4), pp.169–178.
- Zsidisin, G.A. & Smith, M.E., 2005. Managing supply risk with early supplier involvement: a case study and research propositions. *The Journal of Supply Chain Management*, 41(4), pp.44–57.