THE INTER-FIRM COORDINATION OF THE CONSTRUCTION PROJECT SUPPLY CHAIN

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ABSTRACT

The application of supply chain management to construction has been a challenging task. An important reason for that is the difference between the industrial context where it was originated and the construction industry. Although the literature suggests that the use of multiple theoretical approaches can provide a comprehensive description and understanding of construction supply chains, so far no framework has been offered for their joint use in practical situations. This paper aims to provide a multi-theoretical approach that can be used to comprehensively describe inter-organizational coordination of construction project supply chains. The use of three theoretical approaches is discussed: the Theory of Coordination (TC), the Transaction Costs Theory (TCT) and the Language/Action Perspective (LAP). A case study is presented to illustrate the joint use of these three theoretical approaches in a practical situation. The study shows that the three theoretical approaches are highly complementary and that their joint use provides a comprehensive view of how such construction project supply chains arise, develop and finally disband.

KEY WORDS

Supply chain management, inter-firm coordination, project management.

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INTRODUCTION

The application of supply chain management (SCM) practices to construction has been investigated by the lean construction community for a long time. Since the first article on this theme was published at 1995 IGLC conference, SCM has been consistently present in all conferences held by the Group. Despite the progress that has been achieved on the application of SCM to construction, it is still a challenging issue, due to the difference that exists between the original context of SCM and the construction industry.

SCM was originated in industries where demand is predictable, the requirements for variety are low, and volume is high (Christopher, 2000). Most contemporary academic work on the field is related to high volume industries like automotive and electronics, where a large-scale (hence economically powerful) manufacturer is supported by smaller (economically weaker) suppliers or subcontractors (Bresnen, 1996).

In the construction industry, however, the nature of organization is essentially temporary, the products are one-of-a-kind, and the production is on-site and characterized by high levels of complexity (Bertelsen and Koskela, 2004; Vrijhoef and Koskela, 2005). Also, the production process is essentially project-based, and the construction project itself can be considered as a temporary multi-organization (Cherns and Bryant, 1984).

Much of the research effort that has been made in order to translate SCM to construction has been directed towards a better understanding of how real construction project supply chains are actually managed. Vrijhoef, Koskela and Howell (2001) have called the attention for an alternative interpretation of construction supply chain based on the management of commitments among supply chain members. O'Brien (2002) has made a call at the IGLC10 conference for the use of comprehensive models (cost and reference models) to describe construction supply chains. At the same conference, O'Brien, London and Vrijhoef (2002) has proposed an interdisciplinary research agenda for the field. One year after, Vrijhoef, Koskela and Voordijk (2003) has suggested that the use of multiple theoretical approaches for inter-organizational relationships could provide comprehensive understanding of construction supply chains.

Also, research on the application of supply chain management to construction has been related primarily to the construction industry as a whole, or to its companies' supply chains. Supply chains that arise due to construction projects have very rarely been the focus of attention, and when this happens they are in general analysed from the point of view of the client or the most powerful company that takes part on it. But because of the temporary nature of the construction project and the existence of project-specific transactions, its supply chain differs from the company supply chain in that it arises, develops and finally disbands. Due to the specialization of the work and the fragmentation of the overall process among supply chain members, it is not possible to assume that a single firm would have the power or the ability to individually coordinate the whole supply chain, but that every member can influence – and be influence by – the whole supply chain.

Taking this into consideration, this study proposes a multi-theoretical approach that could be used to comprehensively describe inter-organizational coordination of construction project supply chains.

THE CORE CONCEPTS OF SUPPLY CHAIN MANAGEMENT

The literature about SCM is characterised by a number of different interpretations and definitions for supply chain and its related activities, most of them overlapping or contradicting the others

(Tan, 2001; Ross, 1998). However, some common points can be identified in the existing literature in the field.

One of the core concepts of SCM is the systemic approach adopted for the inter-organizational coordination (Forrester, 1961). Nonetheless, Checkland and Scholes (1990) alert that defining 'systemic' can be a tricky task, suggesting that a system that is made of people (a 'human system') can be defined by the presence of the following characteristics:

a) *emergent properties*: a complex whole that may have properties which refer to the whole and are meaningless in term of the parts which make up the whole,

b) *layers of hierarchy*: there are different levels of organization, as atoms, molecules, cells and organs, each one corresponding to distinct emergent properties,

c) *communication and control*: parts and layers communicate one with the other and coordinate their actions, giving to the system the ability to survive in a changing environment, adapting itself in response to shocks from the outside, and

d) *common purpose*: parts and layers must have a common purpose, which is responsible for keeping them together and also for defining the system boundaries.

Based on this, a construction project supply chain can be regarded as a specific kind of human system made of multiple firms that are connected through economic linkages and conceived with the purpose of delivering a construction project. According to this definition, the *firm* is the fundamental block that builds a project supply chain, stressing that the organizations properties (and not the individual's properties) are the main factors to be taken into consideration for describing and understanding inter-firm coordination.

Another concept that is closely associated with SCM is the notion of a chain made of distinct economic agents that are connected by the processes or flows that occur among them. In general, the literature mentions four kinds of flows: the flow of products (subjects of the work), the flow of information, the flow of money and the flow of value. Most of the supply chain management literature considers the flow of value as the most important one, usually encompassing all the other flows (Rother and Shook, 1998).

Taking those flows into consideration, three distinct dimensions of coordination can be identified:

a) The *process* dimension: the purpose of the supply chain is to provide value. It comprises the flow of the objects of the work: products or, in managerial processes, the share of the information flow that carries value.

b) The *social* dimension: the purpose of the supply chain purpose is to coordinate actions of people and firms, the subjects of the work. It includes the flow of the information that is intended to coordinate the work among people (the performative conversation) or to create a common context among people for mutual understanding (the informative conversation).

c) The *economic* dimension: the purpose of the supply chain is to provide the economic stimulus for the firms to take part in the exchanges that are necessary for delivering value to the customer. It includes the flow of money and other resources that take part in the economic exchange.

Due to their complementary nature all of those three flows must be simultaneously coordinated. If not, there is a risk of supply chain collapse due to the lack of cooperation (failure in the economic dimension) or poor coordination (failure in the social dimension) among their members, or even due to the loss of the competitiveness of the supply chain (failure in the process dimension).

LIMITATIONS OF EXISTING APPROACHES FOR MODELLING SUPPLY CHAINS IN CONSTRUCTION PROJECTS

A number of different modelling approaches have been proposed to describe supply chains or explain their behaviour. However, there are some limitations for applying existing modelling techniques mainly due to the fact that most of them seek to describe or explain a specific aspect of the supply chain management. The application of those approaches to construction is suggested by O'Brien (2002) and O'Brien, London and Vrijhoef (2002). Three of the most important among them are discussed below: the model proposed by Lamber and Cooper, the Value Stream Macro Mapping (VSMM) and the Supply Chain Operations Reference Model (SCOR).

Lambert and Cooper (2000) have proposed a theoretical model that describes a supply chain through its business processes, its network structure and the management components that are used. That model, although providing useful insights for the analysis, comparison and design of supply chains, has a major drawback of been anchored in the concept of a "focal company", i.e. the point of view from which the supply chain is to be appreciated. In construction projects, however, it is generally not a single company but the project itself that is assumed to perform this focal role. Another limitation is that only the buyer-seller linkages among firms are taken into consideration. However, as Williamson (1985) and Taylor (2002) suggest, the linkages among other members can be as relevant as the former for the cooperation among groups.

Womack and Jones (2002) have devised an approach for modelling supply chains named Value Stream Macro Mapping (VSMM), based on the Value Stream Mapping technique (VSM) (Rother and Shook, 1998). The VSMM have extended the original VSM approach to the entire supply chain, focusing on the value flow in the chain, aiming to provide means for measuring improvements in terms of waste and lead time, as a way to include suppliers and distributors in the efforts for improving the management of the supply chain. Attempts of applying VSM and VSMM to construction has been reported on Fontanini and Picchi (2004), Pasqualini and Zawislak (2005) and Bulhões, Picchi and Granja (2005), most of them of exploratory nature. In spite of the promising results, they are still limited by the fact that VSM/VSMM approach – as in the model proposed by Lambert and Cooper – assumes that the analyses of the supply chain must be made from the perspective of a single company.

Another important contribution for supply chain analysis and design has been provided by the Supply Chain Operations Reference Model (SCOR), proposed by the Supply-Chain Council (2004). It includes a common terminology and a set of standardized processes that could aid in the description and redesign of supply chains, favouring the comparison among supply chains from distinct companies or industrial sectors. These characteristics greatly contribute to abstract, transfer and generalize supply chain practices across different industries through benchmarking. However, a serious limitation for its application to the description of construction project supply chains is that it does not includes the design processes, which is of critical importance in engineering-to-order industries, such as construction.

THEORETICAL APPROACHES FOR INTER-FIRM COORDINATION DESCRIPTION AND ANALYSIS

In order to describe a supply chain in terms of the coordination among its members, the three dimensions of coordination that were discussed above must be taken into consideration. Thus, three questions might guide this choice: (i) how to organize the work among supply chain members?, (ii) how to achieve and maintain cooperation among these firms?, and (iii) how to coordinate processes execution among people from different firms that enjoy a high degree of autonomy?

Three theoretical approaches were identified in order to help to answer those questions: the Theory of Coordination, the Transaction Costs Theory and the Language-Action Perspective.

The Theory of Coordination

The theory of coordination was originally proposed by Crowston (1991), and built on previous work of March and Simon (1958) and Thompson (1967). According to this theory, coordination is regarded as "... the act of managing dependencies among activities" (Malone and Crowston, 1994). Crowston (1991) states that those dependencies among tasks[3] demand some kind of management, thus making it necessary the design and implementation of special tasks aimed to this specific purpose.

In the coordination theory, such activities can be generalized in the form of *coordination methods*, and an adequate coordination method exists for every kind of dependence. Crowston (1991) suggests that the description of coordination problems can be made in terms of tasks creating and using resources (i.e., a task-resource relationship). The same author also identified three types of task-resource dependencies and associated them to the specific coordination methods:

a) *Flow dependencies*: in this kind of dependence, the resources that are produced by one activity are used by another one. The management of such kind of dependence involves the decision about when each task is to occur and when the resources are to be transferred between them, and the quality of such coordination can be assessed by three perspectives: *pre-requisite* (the resource must be made available by the first task at the time it is needed by the second task – the right time), *usability* (the quality of the resource must be adequate for its use – the right thing) and *availability* (the resource must be available in the right place).

b) *Use or creation of common resources (concurrent dependences[4])*: Crowston (1991) notes that the nature of the common resources plays a critical role in the nature of the coordination problem. According to him, those resources can be classified as *shareable*, *non-shareable and reusable*, *and non-shareable and consumable*. A summary of possible coordination problems is presented in Figure 1.

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3 Despite of the fact that Crowston (1991) does not explicitly differentiate *activities* and *tasks*, for the sake of clarity it is assumed in this article that tasks are activities which are assigned to roles or to specific actors.

4 The term 'concurrent dependence' was not proposed by Crowston but by these authors, for the sake of clarity of the text

Use	Types of resource		
	Shareable	**Non-shareable and reusable**	**Non-shareable and reusable**
Create - Create	Eliminate duplicate Negotiate object	Share object	Economies of scale
Use - Use	No conflict	Schedule use	Conflicting goals (favouring one task instead of another)

Figure 1: Typology of coordination problems by operations and type of common object (Crowston, 1991)

c) *Dependencies among tasks and sub-tasks*: this coordination problem usually arises in situations involving the division of work and the assignment of sub-task to different actors. For the accomplishment of the original task all sub-tasks need to be finished. Thus, the original task can be viewed as a main goal to be achieved, and its sub-tasks as intermediary or secondary goals. Malone *et al* (1999) have identified two ways of decomposing a task. The first is by dividing the original task into smaller and more specific ones, usually resulting in flow dependencies among them. The other approach – called specialization – is to decompose the main task in distinct in sub-tasks that can share resources among them and are generally run simultaneously. Both logics are represented by Malone *et al* (1999) as a "process compass" (Figure 2), used to analyse business processes.

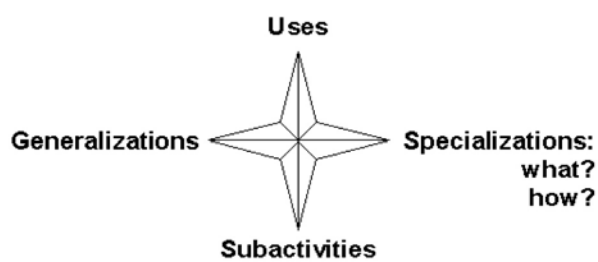


Figure 2: The "Process Compass" - Two dimensions for analysing business processes (Malone et al, 1999)

Transaction costs theory

A serious limitation for the application of coordination theory to the inter-organizational sphere is that it assumes that "*... actors are essentially cooperative, that is, that their goals mostly do not conflict and when asked to do something, they do it.*" (Crowston, 1991, p. 51).The transaction costs theory (TCT), originally proposed by Ronald Coase in 1937 and extended by Williamson

(1985), can be used as a complementary approach to explain how such cooperation among firms is obtained and maintained.

In spite of the fact that the motivation for cooperation in inter-organizational context arises essentially from economical reasons, TCT explicitly considers that “cooperation is jointly determined by social factors and incentive alignment” (Williamson, 1985, p.6). Its assumptions are basically behavioural: economic transactions occur in a context characterized by the presence of *opportunism* (“self-interest seeking with guile”, as defined by Williamson, 1985) and that the human agents are subject to *bounded rationality* (their behaviour is intendedly rational but only limitedly so, as stated by Simon, 1961).

Thus, the problem that has been posed by Coase and by Williamson (1985) was of “...[devising] contract and governance structures that have the purpose and effect of economizing on bounded rationality while simultaneously safeguarding transactions against the hazards of opportunism” (Williamson, 1985, p. xiii).

The TCT explicitly takes into consideration what happens before contract celebration (the *ex ante* cost of contracting) and also during its execution (the *ex post* transaction costs)[5]. Behavioural aspects establish an important link between *ex ante* and *ex post* costs, and both of them must be addressed simultaneously rather then sequentially.

In TCT, transactions can be described by their frequency (recurrent or occasional) and the characteristics of the investment that they involve (asset specificity – non specific, mixed and idiosyncratic). Such characteristics will dictate the most adequate governance structure do be adopted for the transaction, which should be the one that minimize overall transaction costs.

For transactions that involve non-specific assets, the market (classical contracting) will be the most adequate governance form. On the opposite, highly idiosyncratic and recurrent transactions tend to be governed through the unified governance (i.e., inside the firm). Between those two extreme governance forms there is a *continuum* that includes specialized governance structures: the trilateral governance (neoclassical contraction) and the bilateral governance (relational contracting).

In situations characterized by recurring transactions that are supported by investments of mixed kind, relational contracting often reveals to be the most adequate governance structure. The recurrence of transactions justifies the need for a highly specialized governance structure, in which aspects as trust and mutual interest drive a long term relationship. In relational contracting, the original agreement not rarely looses its importance as the main reference for the relationship since new rules and practices are mutually agreed by both parties during contract execution.

When occasional transactions are supported by investments of mixed and idiosyncratic nature, the costs involved in setting up and running a bilateral governance generally cannot be recovered. However, once the parties have agreed in a contract strong incentives arise in order to see the contract through to completion due to the specificity of the assets. In such situations, the classical contracting is unsatisfactory because of the cost and time involved in a possible

[5] As Williamson (1985) points out, the first are the costs of drafting, negotiating, and safeguarding an agreement. The latter can take several forms, including (a) the maladaption costs incurred when transactions drift out of alignment, (b) the haggling costs incurred if bilateral efforts are made to correct *ex post* misalignments, (c) the setup and running costs associated with governance structures (often not the courts) to which disputes are referred, and (d) the bonding costs of effecting secure commitments.

conflict resolution by the courts. The neoclassical contracting scheme offers an alternative for classical and relational contracting by introducing a third-party assistance (arbitration) in resolving disputes and evaluating performance. Unlike the bilateral governance, the original agreement remains as the basis of the relationship in trilateral governance, serving as the reference for contract execution and arbitration.

The most adequate governance structure for each combination of frequency and investment characteristics is presented in Figure 3.

Frequency	**Investment characteristics**		
	Non specific	**Mixed**	**Idiosyncratic**
Occasional	Market governance (classical contracting)	Trilateral governance (neoclassical contracting)	Trilateral governance (neoclassical contracting) or Unified governance
Recurrent	Market governance (classical contracting)	Bilateral governance (relational contracting)	Unified governance

Figure 3: Efficient governance (Williamson, 1985)

The Language / Action Perspective

Neither the Theory of Coordination nor the Transaction Costs Theory addresses how to coordinate actions (i.e., the collaboration) among members of the supply chain that have high levels of autonomy.

The language / action perspective (LAP) has shown to be a promising approach to answer this question. It was proposed by Fernando Flores (Flores, 1982), who has suggested that the language could be intended to create a mutual orientation among different actors, in a kind of 'social action' which, in turn, results in changes in the real world. According to Flores (1982), we engage in commitments when we speak, which in turn generate action. Thus, the effective coordination of actions can be considered the same as the management of commitments, and the progress of work can be traced by watching speech acts in the communications of those coordinating (Flores, 1982).

Winograd and Flores (1986) have suggested that the breakdowns experienced by organizations are a direct consequence of the failures that occur in those speech acts. They have claimed that business processes (and organizations themselves) are intentional efforts to anticipate breakdowns. Macomber and Howell (2003) and Howell *et al* (2004) have pointed out that commitment management is at the core of the Last Planner System^{TM} and that the LAP are a promising approach for the management of lean projects.

Based on Flores (1982) and on Winograd and Flores (1986), Denning and Medina-Mora (1995) suggest that commitments can be regarded as work-flow loops, and that every organization is a network of commitments. According to those authors, an organization can be depicted as a map of interconnected commitment loops, which could be used as a guide to design work processes and their supporting information technologies (Denning and Medina-

Mora, 1995). Every loop is a business transaction that involves two parties: one of them (the 'performer') promises to satisfy a request of the other (the 'customer'). Also, every loop is made of four phases, and the completion of each phase occurs by the utterance of a specific kind of sentence by the performer or the customer (Figure 4).

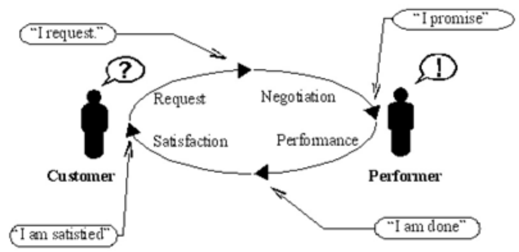


Figure 4: The commitment loop (Denning and Medina-Mora, 1995)

THE DESCRIPTION OF INTER-FIRM COORDINATION OF A CONSTRUCTION PROJECT SUPPLY CHAIN: AN ILLUSTRATION

Project description

The construction project that will be used to illustrate the joint application of the three theoretical approaches consisted of the building of a new lab (1607 m_) and the adaptation of an existing one (832 m_) for a petrochemical company, in Triunfo, a town form the State of Rio Grande do Sul, South of Brazil. A six month period was agreed for project completion, and at the time of the signature of the contract between the client and the general contractor only an architectural outline design was available. The construction stage took place from June to December of 2001.

The organization of the work

The process of organizing the supply chain started by the decomposition of the original task "*install lab*" by the client (CLI), who has decided to break it into three sub-activities: "*design lab*", "*build lab*" and "*install equipment*". Then the first (*"Design lab*") was broken down into "*make the lab's draft design*", "*make architectural design*" and "*make sub-systems design*". The activities of making the lab outline and architectural design was assigned by the client to an architect (ARC), and then the activities of designing sub-systems and building the lab to a general contractor (CON). The activity "*install equipment*" remained unassigned, and thus under the responsibility of the client. The general contractor decided to subcontract each of the subsystems, breaking down the overall task of designing and producing/installing subsystems into the various specialties, and assigning each of them to a different subcontractor (SC1, SC2, ... Scn). The Figure 5 shows the dependence among tasks and sub-tasks involving the firms that took part in the project.

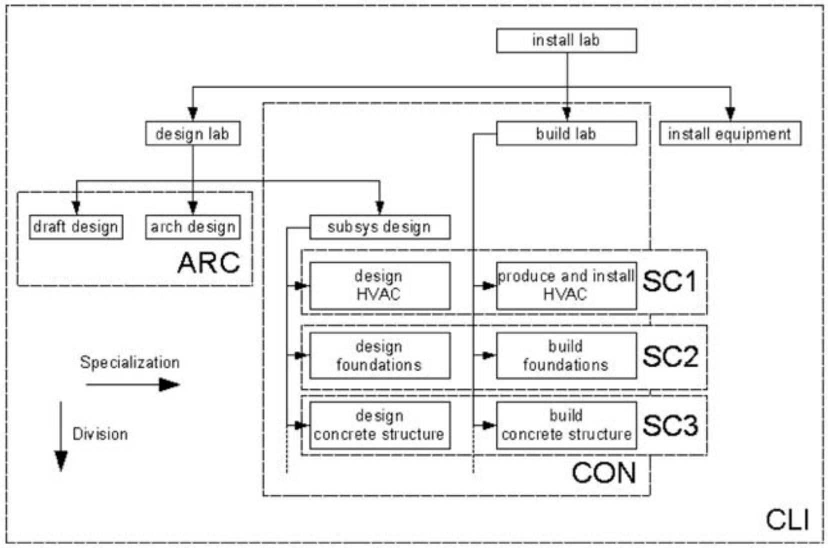


Figure 5: Task decomposition and assignment among firms

The flow of dependencies that arose from those decisions are shown in Figure 6. The client was responsible for coordinating the flow (i.e., assuring the pre-requisite, availability and usability) of information about user requirements to the architect and to the general contractor dependencies, as well as the flow of information about architectural definitions from the architect to the general contractor. The client was also responsible coordinating the delivery of the building from the general contractor for the installation of equipment.

At a lower level, the general contractor was responsible for coordinating the flow of information about architectural definitions to the subcontractors, as well as the flow of the sub-systems to the site.

Those flow dependencies demanded different mechanisms to coordinate the flow among actors. At the project start, the general contractor took the initiative of promoting weekly meetings with the architect, the client and subcontractor in order to assure the quality and timing of product development. The primary purpose of those meetings was to identify the needs of production and to establish deadlines for the delivery of design definitions. Simultaneously, the delivery of the installation of subsystems on site was coordinated through weekly meetings on site among the general contractor and the subcontractors, and according to production plans prepared for the same period of time.

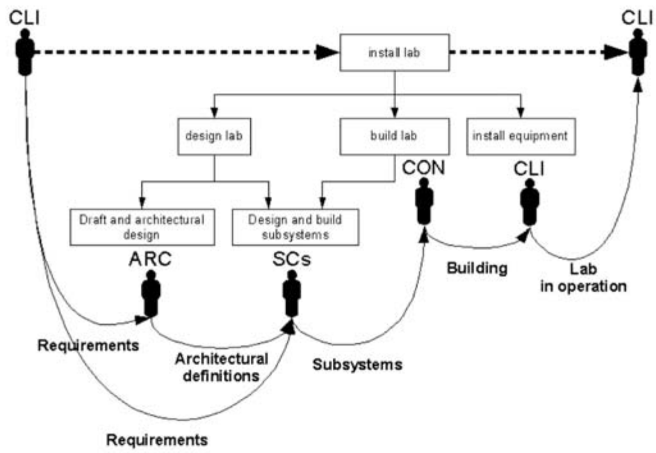


Figure 6: Flow dependencies among actors

Initially, the flow of architectural definitions between design and production was planned to be pushed from the former to the latter. Since the sequence of design differs significantly from the sequence of construction activities, an intermediate buffer of architectural definitions was set up to assure pre-prerequisite consistency between the architect and subcontractors. However, later changes of client's requirements affected the usability of many of the previous architectural definitions that formed that intermediate buffer, reducing its size and thus making it necessary increasing levels of concurrency between design and production.

These has driven the project supply chain to adopt a pull coordination system between design and production and very small transfer batches of information at a time, usually the equivalent of one-week's work of the designers or even less.

Among the subcontractors, the dependences were managed mostly as they were of the type of use or creation of common resources since the architectural definitions and client's requirements were common resources that need to be concurrently used by each of the designers (use-use dependence). Also, each of the resulting subsystems definitions must be well integrated with the others for creating the product design as a common resource (create-create dependence).

A number of actions were undertaken in order to manage such concurrent dependences. Firstly, the attendance of all the designers, general contractor construction company and client representatives to the weekly meetings were enforced in order to enable the establishment of the necessary commitments (more precisely, enabling the request, negotiation and satisfaction phases of commitment loops). Secondly, the use of electronic documents was established by the design team as the regular practice to exchange information among them thus making the design definitions a shareable and reusable resource. Thirdly, a project extranet was set up to provide simultaneous access to such information for all the team and to notify team members of the accomplishment of planned tasks (signalling the conclusion of the execution phase of commitment loops). Fourthly, rules for naming and controlling the many versions of the drawings were accorded among the design team to assure the usability of the information to be exchanged among them.

The economic cooperation

The way tasks were decomposed and assigned to the actors has shaped to a great extent the forms of governance adopted in the project. Each of the task assignments involved assets with a high degree of specificity.

Even considering the existence of previous transactions between both the architect and the general contractor with the client, a classical contracting scheme (market governance) was initially adopted. However, changes in clients' requirements and difficulties in planning and controlling the design process among the firms in the first month of the project indicated that the adopted contracting scheme was not the most appropriate one for that context. The need for approval of every change by both the client and the general contractor plus the eventual need of additional negotiation about the scope of contracts have slowed down the speed of the design processes and increased the risk of project delays.

The contracts between the general contractor and subcontractors were of a different nature. Most of them were bilateral arrangements (relational contracting) that were set up by the general contractor aiming to establish long term partnerships with those suppliers. However, even the high flexibility of this contracting scheme was not enough to shield those relationships against the effects of the conflicts between the general contractor and the client. The situation had almost reached an impasse when the client and the general contractor agreed to set the original contract aside and to renegotiate previous conditions. The client acceded to general contractor demands and stopped allowing changes in the design and gave more autonomy to the general contractor. In turn, the general contractor has agreed with the establishment of new deadlines for the project completion. After that, most of the decisions about the design processes were taken directly by architect, subsystem designers and, when necessary, by the general contractor.

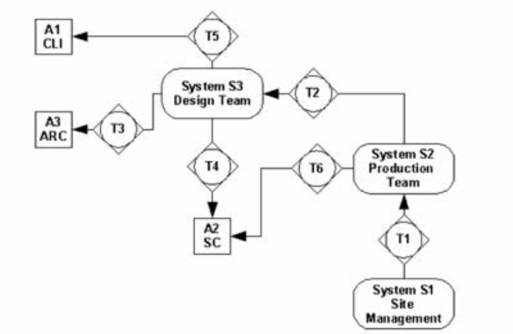
After the renegotiation of the contract and the freeze of the design, the overall governance structure of the project has moved from the original classical (client – general contractor) and relational contracting (general contractor – subsystems contractors) schemes to a trilateral one. In this new configuration the design team played a critical role as a third party in resolving disputes and evaluating performance of relationships between the members of the project supply chain.

It is noteworthy the fact that the decision of the construction company in purchasing complete subsystems as engineered-to-order contracts has simplified to a great extend the task of coordinating the activities under its responsibility, since much of the complexity involved in the coordination of dependencies among the design, production and installation of each subsystem was transferred to the suppliers. However, a price to pay for this decision was the loss of capacity to coordinate directly much of the process due to supplier autonomy, thus increasing its dependency on each supplier.

Processes coordination in the supply chain

At the beginning of the project, the general contractor had already implemented a production planning and control system based on the Last Planner™ and was investigating the possibility of adapting the extending the system to the planning and control of product design. A kind of synchronisation was set up between the weekly meetings of the design and production teams in order to pass the needs of design definitions from production to design in a weekly basis. As the development process became more complex and difficult to preview in the long and medium term, these meetings started to play a central role in the management of commitments among the firms involved, not only in terms of the design process but also in resolving contractual divergences that were related to the product design. The diagram in Figure 7 shows the interactions that were involved in the design and production planning and control of the construction project. Each of the diamonds represents a business transaction (a commitment loop) between a requester and a performer, which can be either an individual firm (an actor An) or a set of firms (a system Sn).

The actions were coordinated among the actors essentially through the establishment of weekly commitments and monitoring their accomplishment. A project extranet helped to increase transparency and to decentralize this task by notifying task accomplishments to the members between weekly meetings.



Transactions		Actors/ Systems	
T1	Plan production	A1	Client
T2	Design product	A2	Subcontractor
T3	Design architecture	A3	Architect
T4	Design subsystems	S1	Site management (General contractor)
T5	Provide client requirements	S2	Production team (CON+SCs)
T6	Plan subsystem production	S3	Design team (CON+CLI+ARC+SCs)

Figure 7: Interaction diagram representing transactions in the design and production planning and control processes

DISCUSSION

The case study described above is an illustrative example of how each of the three theoretical approaches complements the others in explaining the phenomenon of the inter-firm coordination in a construction project supply chain.

Although the Theory of Coordination does not addresses specifically situations of temporary organizations nor the inter-firm context, its application to this kind of context helps to understand the way the purpose of the construction project supply chain can be decomposed into smaller tasks and assigned to each of the firms that take part on it. In the case study that was presented, such process of planning the supply chain structure was not conducted by a single company. Instead it assumed the form of a fractal-like organization, as the client had very little influence over the way the general contractor decomposed and assigned the task that are under his responsibility, and nor the general contractor over the subcontractors. Also, the TC has shown that a strong relationship exists between the way tasks are decomposed and assigned and the dependences that arise among the firms involved. Finally, it has called the attention on how the choice of coordination mechanisms could influence the effort involved in the coordination among the supply chain members.

The Transaction Costs Theory has offered an alternative approach for understanding the inter-organizational coordination of the construction project supply chain. Is was derived primarily from its ability in explaining how the mixed or idiosyncratic nature of construction contracts results in mutual interdependence among firms even in situations in which one of the parties proves to be more powerful than the other during *ex ante* phase of a contract.

The main contribution of the LAP was in explaining how managerial processes that occur in the inter-firm context can be coordinated even when little control exists over the sequence and content of the activities from the perspective of a single firm. The management of commitments has shown to be an effective alternative to coordinate the actions among the members of the construction project supply chain even when each of the firms enjoy high levels of autonomy.

Each of the three approaches emphasizes distinct dimensions involved in the inter-organizational coordination of the supply chain. The Theory of Coordination focuses on the process dimension, the Transaction Costs Theory addresses mainly the economic one, and the social dimension is the primary concern of the Language - Action Perspective. At the same time they have shown a high degree of complementarity. The Theory of Coordination and the Transaction Costs Theory are closely linked by the idea of assignments that happen in the economic environment, bridging the gap between the coordination of production and economic flows. By contrast, the LAP helps to explain how coordination processes occur in the space of possibilities that is defined by contracts and other forms of governance that are responsible for defining the expected boundaries of cooperation among the firms. Social and economic flows are then connected by LAP and TCT.

The linkage between the TC and the LAP comes from the link that both approaches offer between the production and the social flows. The TC emphasizes what has to be done and the consequences of the way the tasks are decomposed and assigned, and the LAP complements this by focusing on the information system that is necessary to coordinate actions among people through the management of commitments.

CONCLUSION

This article has proposed the joint use of three theoretical approaches in order to understand how inter-organizational coordination occurs in a construction project supply chain: the Theory of Coordination, the Transaction Costs Theory, and the Language-Action Perspective. The main contribution of this study has been in providing a descriptive framework to better understand the ways supply chains are managed in the particular context of the construction projects.

Some opportunities for further research arise from this study. One is to identify relationships among intra and inter-firm environments in terms of the coordination of construction project supply chains. The identification of such links could help the firms to influence the supply chains in which they participate. A natural consequence that arises from the proposition of this theoretical framework is the possibility of its application to other situations and the conception of predictive models, aiming to directly contribute to the management of construction projects. Among them, reference models that include specific metrics for coordination efficacy are of special interest. The association of these coordination metrics with the performance of the supply chain in terms of waste and lead time could help the application of lean principles to construction project supply chains and facilitate further cross industry comparisons.

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