Elements to Classify Subcontractors Production Systems

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Abstract

Subcontractors are heterogeneous firms that are active in different competitions. They are usually hired on the lowest price bidding basis, disregarding their distinctive characteristics, except in cases of construction projects with unique problems. This condition, coupled with the fact of them being mostly micro and small enterprises, causes the bankruptcy of 50% of them in their fourth year of operation. Past researches discussed the characteristics required in their procurement process. However, little is written about how they are organized and how their role in construction projects alters the way they execute their specific building trades. Our aim is to discuss some elements to classify the Subcontractors production systems. Accordingly, 38 companies of different sizes from Brazil and Spain were interviewed in a qualitative research, analyzing elements from their production systems and from their relation to the phases of construction projects. As a result, some classifications of Subcontractors production systems are proposed. Those classifications can serve several purposes, including: (i) Incorporating Subcontractors different characteristics in the Contractor's procurement process, or (ii) for developing differentiation elements in Subcontractors' specific competitions.

Keywords: Subcontractors, Production Systems in Construction, Competitive Advantage, Brazil, Spain.

1. Introduction

1.1 Subcontractor environment

Subcontractors are fundamental actors to achieve better outputs in the Construction Industry. The notion of subcontractor is related to all the firms that perform building trades and have not been awarded with the main construction contract. They generally perform their building trades in different subcontracting tiers (Oviedo Haito, 2010), as specialty contractors, trade contractors and their subcontractors. They are the main participants in a Construction Project –almost 80-90% of the construction work– (Hinze and Tracey, 1994). Also, in developing countries, such as Brazil, where the construction industry represents 8.9% of the Brazilian GDP, subcontractors are an important source of employment.

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Regardless of the differences between subcontractors' services and building trades, they are generally contracted on a basis of lowest-price bid in a competitive tendering process (Dainty *et al.* 2001). Along with these features, subcontractors are characterized for been mostly micro, small and medium enterprises (SME) with lack of resources and competences and low power to change their competitive positioning (Oviedo Haito, 2010). In emerging economies, such as Brazil, subcontractors receive poor condition to work at the construction site and poor contracting conditions (Oviedo Haito, 2010). This, joined to the lack of resources and competences of many of them being SME, lead them to have little capacity to fit their competitive environment; as a result, 50% of them go bankrupt on their fourth year of activity (Sebrae-SP, 2010).

Thornhill and Amit (2003) discussed the importance of having the right resources and competences to the success or failure of a firm. For Amit and Schoemaker (1993), those are the strategic assets of the firm. There are several classifications to those assets. For Empson, (2001) the assets are: reputation, experience, skill and knowledge of the employees are the essential resources. To Anvuur and Kumaraswamy (2008) the capitals are: Physical Capital, Human Capital, Structural Capital and Social Capital. To Oviedo Haito (2010), the strategic assets of a subcontractor are: Physical asset, Financial asset, Human Capital, Organizational Capital, Relationship Capital and Reputational Capital.

Regarding Relationship or Social Capital, the latest efforts in construction collaboration and partnering (Smyth and Pryke, 2008) must be important to change this antagonistic environment. Nevertheless, the relationship between subcontractors and their clients is mostly adversarial and distrusted (Hinze and Tracey 1994, Kumaraswamy and Matthews 2000). This relationship could be improved if their clients recognize the heterogeneity of subcontractors and transform this into an alternative selection process, in contrast to the dominant lowest-bid based on competitive tendering criteria.

A way to do this is by identifying some differences in subcontractor's production systems.

1.2 Manufacturing and production systems in construction

Discussions led by the current concern about the sustainability of the Building Industry revives the interest of the industrialization of construction - and their manufacturing and production systems - especially by increasing the offsite manufacturing at the expense of traditional onsite works (Ekholm 1996, Taylor 2008, Kamar *et al.* 2009, Azzi *et al.* 2011, Taufiq 2011, Jonsson and Rudberg 2012).

This discussion may be decomposed into two main aspects: the product to be built and the process to build that product. On the Product aspect, Cardoso (1996) discussed 3 places of producing parts and components of a building: Offsite and Onsite; dividing onsite in: other installations and the frontline. In those places, Jonsson and Rudberg (2012) distinguished four types of manufacturing systems in construction: Component manufacture & sub-assembly, Non-volumetric pre-assembly, Volumetric pre-assembly, and Modular Building.

Thus Jonsson and Rudberg (2012) defined: "**Component manufacture & sub-assembly**: the traditional approach in construction in which raw materials and components are used for building on-site; **Non-volumetric pre-assembly**: "two-dimensional" elements pre-fabricated off-site and assembled on-site; **Volumetric pre-assembly:** Volumes of specific parts in the building are produced off-site, and assembled on-site within an independent structural frame; and **Modular Building**: in which much of the production is made off-site, with modules fabricated to a high level of completion. The only work performed onsite is the assembly of the modules and finishing operations".

To Kamar *et al.* (2011), these components are the basis for migrating from traditional construction to more efficient ways to build. In this sense, they described three ways: **"Modern Method of construction (MMC)**: Number of innovations in building most of which are offsite technologies, moving work from the construction site to the factory; **Non-industrialized innovative solution**: is the use of an innovation method that has been verified in other industries; **Industrialized building system (IBS)**: is an innovative process of building construction, using the mass-production concept of industrialized systems, produced at the factory or onsite within controlled environments, it includes the logistic and assembly aspect of it, in proper coordination with thorough planning and integration". The relation among these concepts and others is presented in Figure 1.

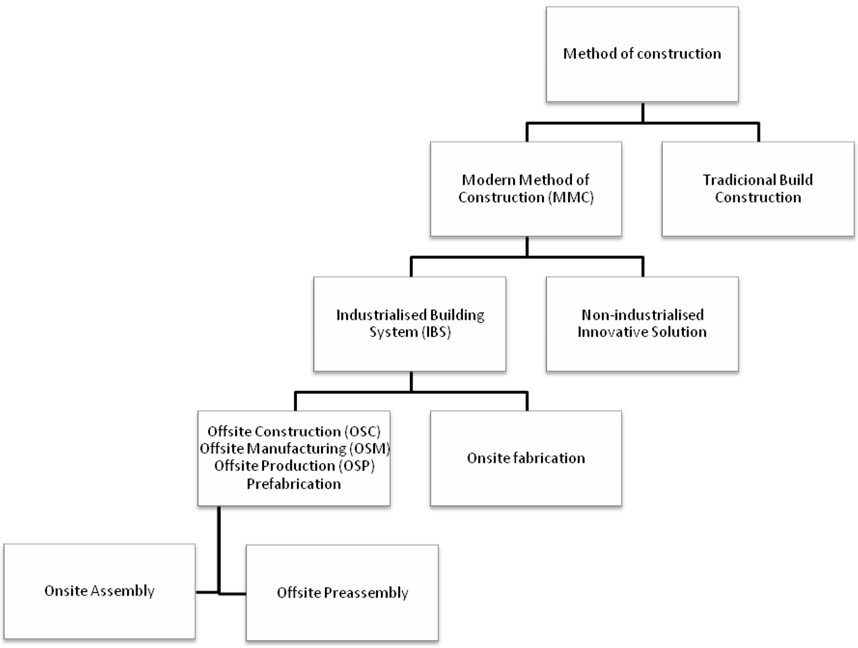

Figure 1: IBS and other Terms to describe industrialization in the method of construction (Adapted from Kamar et al., 2009)

Regarding the Process aspect of Production systems in construction, Sabbatini (1989) discussed concepts of industrialization and rationalization of the construction process. He defines industrialization as an evolutionary continuous improvement process of the organization of a holistic and systematic 'mode of build', characterized by the use of principles of manufacturing or industrial organization (PDCA approach), by the use of other facilities onsite for intermediary transformation, assembly or prefabrication and or offsite manufacturing and prefabrication of components and elements of the building, by the mechanization of operations, and by the incorporation of technological innovations that improve the overall performance of the product and their production process.

For Sabbatini (1989), rationalization is an intermediary stage between traditional and industrialized modes of build, which constitutes an innovation to the traditional mode. It is related to the improvement of a traditional 'mode of build' by turning it rational, incorporating management principles from the industrial organization, moving the knowledge from the craft of construction activity to design, planning and control stages; by the use of onsite prefabrication or assembly of building components and by, when required, the mechanization of the operations, mainly regarding transportation activities. Adversely, Traditional 'mode of build' is a craft dependent mode of build characterized by the absence of a systematically organized and well defined work process.

Complementarily, Cardoso (1996) defines the Production Process of a Building as the set of stages arranged over time, from concept to operation, in that several agents (from client to subcontractors) interact to carry out the whole Construction Project. He also defines the Building Production System as being a part of a Production Process in which physical and managerial (including, among others, logistics and procurement) operations are articulated and integrated around Product Design and Process (construction) Design. Cardoso's (1996) approach, based partly on Sabbatini´s (1989) work, implies that the ´mode of build´ must be rationalized as a process, defining competences, methods, the managerial approach and the organization of building before beginning onsite construction operations.

In other words, the rationalization and industrialization of a (traditional) 'mode of build' is materialized by incorporating the construction knowledge at the early stages of the Building Production Process, mainly in the Design phase and by designing an efficient mode of build. This proposition is represented in Figure 2.

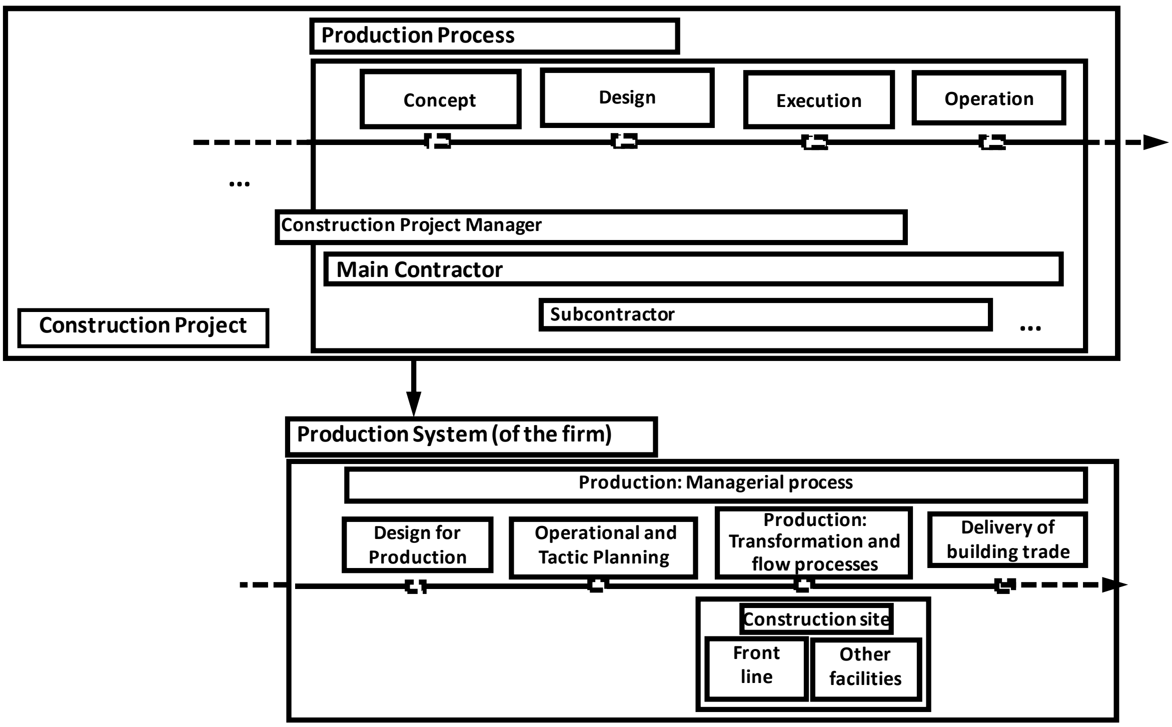

Figure 2: The Concept of Production Process and System of a building trade (Adapted from Cardoso, 1996)

Winch (2003) also discusses that the process flow of a Construction Process can be divided into Concept, Design, Planning, Manufacture, Assemble and Control stages. At a General Contracting system, Design and Planning stages, as a rule, intentionally exclude any subcontractor participation (except for some specialty and trade contractors such as Cladding and Mechanical systems). In emerging countries, as is the Brazilian case, there is little time between the awarding and the beginning of subcontractors' building trades, leaving the latter with little time for planning their production.

However, planning is different from the construction project level, when compared to the level of detail required for the operations of a subcontractor. In a traditional construction project organization, information is detailed up to the work package level, producing rough estimation of work. This information is useful for the tendering process for selecting a subcontractor to do the work, but insufficient to describe the mode of build, transferring this task –and the related risk– to subcontractors.

As shown in Figure 2, this system approach uses the Design for Production approach. In this sense, Maneschi and Melhado (2010 p.9) said: "in civil engineering, product design aims to define the product conceived, being a graphic and descriptive recorder of the product that will be built, while design for production aims to define how to produce the product".

Design for Production (Manneschi and Melhado 2010) is a tool been used in Brazilian Building Construction, mainly to ensure the transmission of information with enough detail to the trade builder do their work as a process, assuring quality on the execution of building works made by, in several cases, disqualified labor. For Sabbatini (1989), Design for Production is a mean to ensure the transmission of construction knowledge , reducing – among others - the need of labor qualification.

Also, Kamar *et al.* (2009, p9) discussed that the "...degree or level of industrialization is also associated with the scope of work in the construction process or life cycle. As compared to the traditional method, the prefabrication scope of work involves more planning".

As highlighted by Vargo and Lusch (2008), the scope of work in a service, or the value proposition of a firm can be described as a function of the valued resources the firm deploys to do their service. This is based on the seminal work by Penrose (1959), who said "it is never *resources* themselves that are the 'inputs' to the production process, but only the *services* that the resources can render" (pp. 24–25; italics as in the original version).

Hence, Oviedo Haito (2010) discussed several scopes of subcontractors' work, all of them associated with six strategic assets: Physical asset, Financial asset, Human Capital, Organizational Capital, Relationship Capital and Reputational Capital. An Australian work studies differences in services provided by construction suppliers, identifying a set of value-adding activities (Manley and Marceau, 2002). From that, some possibilities we highlight are Design, Project Management, Supply, Manufacturer, Distributor, and Installation.

As a result of this literature review, we identified some Elements for Classifying the Subcontractors' Production System, as shown in Figure 3.

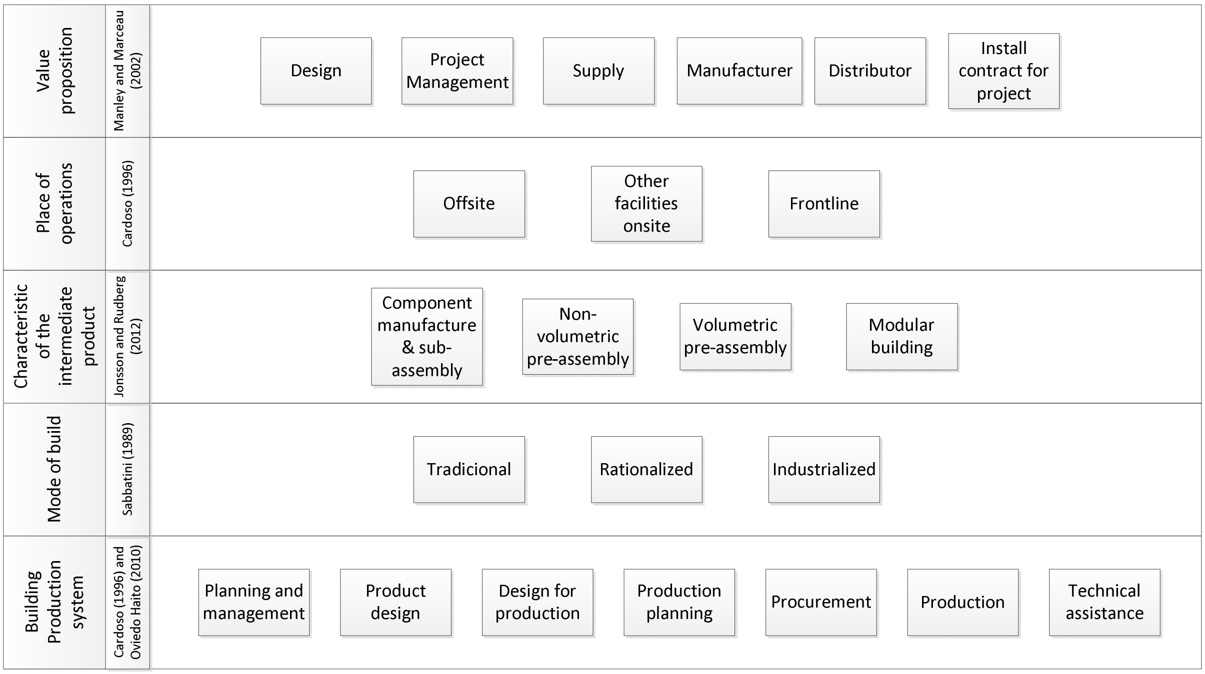

Figure 3: Literature-based elements for Classify a Subcontractors' Production System

2. Objective

The aim of this paper is to discuss some elements to classify the production systems into Subcontractors. A classification *per se* is not the objective, but a means to interpret the characteristics of the subcontractors as a function of the elements identified.

3. Methodology

To accomplish the objective, a qualitative research was performed. In-depth interviews were conducted with 38 subcontractors from Brazil and Spain, selected by purposeful sampling and snowball technique (Patton, 1990). They were asked about the means used for their production process and characteristics of their building trades. The questionnaire was based on the work by Oviedo Haito (2010). Data was collected and compared with the categories taken from the literature review. Accordingly, data was compared and sorted, as shown in the next item.

4. Results

Based on the literature revision, five major categories were identified to compose a classification, shown in Figure 3: Value proposition, Place of operations, Characteristic of the intermediate product, Mode of build, and Production system. As a result, Table 1 shows how these characteristics fit the subcontractors interviewed.

Table 1: Elements for Classifying the Subcontractors' Production System identified in 38 subcontractors

				Value adding possibilities				Place of most operations							Production System						
Firm	Building trade	Firm Age (years)	Number of employees	Design	Project Management	Supply	Manufacturer	Offsite	Other facilities	Frontline	Characteristics of the intermediate product	Mode of build	Product Standardization	Component Standardization	Planning and Management	Product Design	Design for Production	Production Planning	Procurement	Production	Technical Assistance
1	Masonry, internal and external coating, and subfloor	15	200		1				1	1	CM	R	H	H	1		1	1	1	1	1
2	Masonry, internal and external coating, and subfloor	12	295		1	1			1	1	CM	R	M	M	1			1	1	1	1
3	Masonry, internal and external coating, and subfloor	3,5	96			1			1	1	CM	R	H	H					1	1	1
4	Fenestration, doors, frames and hardware	2	46	1	1	1	1	1	1	1	NV	T	M	H	1	1	1	1	1	1	1
5	Masonry	4	376		1	1	1		1	1	CM	R	H	H	1		1	1	1	1	1
6	Electrical wiring and communications	17	11		1	1				1	CM	T	H	H	1		1	1	1	1	1
7	Foundations	75	400	1	1	1		1	1	1	CM	R	H	H	1	1	1	1	1	1	1
8	Water proofing systems	26	200	1	1	1			1	1	CM	R	H	H	1	1	1	1	1	1	1
9	Exterior coating and Concrete structures (including Prestressed Concrete structures)	20	1250		1	1			1	1	CM	R	H	H	1		1	1	1	1	1
1	Water proofing systems	17	180	1	1	1			1	1	CM	R	H	H	1	1	1	1	1	1	1
11	Laminate flooring	13	17		1	1			1	1	CM	T	L	H	1		1	1	1	1	1
12	Masonry, internal and external coating, and subfloor	6	13		1				1	1	CM	R	H	H	1			1	1	1	1
13	Laminate flooring	18	15		1	1			1	1	CM	T	L	H			1	1	1	1	1
14	Gypsum Plaster	16	20		1	1			1	1	CM	T	L	M	1			1	1	1	1
15	Laminate flooring	5	41		1				1	1	CM	T	H	H	1			1	1	1	1
16	Dry Wall	4	37		1	1			1	1	CM	R	L	H	1			1	1	1	1
17	Dry Wall	2,5	30		1	1			1	1	CM	R	M	H	1		1	1	1	1	1
18	Electrical maintenance	3	3		1					1	CM	R	M	H	1			1	1	1	1
19	Fenestration, doors, frames and hardware, glass and glazing, and metal panels	7	29		1		1	1	1	1	NV	R	M	H	1			1	1	1	1
20	Laminate flooring	8	8		1				1	1	CM	T	L	H	1			1	1	1	1
21	Fenestration, doors, frames and hardware, glass and glazing, and metal panels	37	24	1	1	1	1	1	1	1	NV	R	H	H	1	1	1	1	1	1	1
22	Dry Wall	1	100		1	1			1	1	CM	R	M	H	1		1	1	1	1	1
23	Masonry, internal and external coating, and subfloor	15	500	1	1	1			1	1	CM	R	H	H	1	1	1	1	1	1	1
24	Masonry	11	350	1	1	1	1		1	1	CM	R	H	H	1	1	1	1	1	1	1
25	Painting & Decorating	30	350		1	1				1	CM	T	L	H				1	1	1	1
26	Precast concrete facade panels	16	65	1	1	1	1	1	1	1	MB	I	H	H	1	1	1	1	1	1	1
27	Maintenance of civil infrastructures and gardening	25	200		1	1		1		1	CM	R	L	H	1			1	1	1	1
28	Foundations and structures of reinforced concrete	11	50		1	1			1	1	CM	T	M	H	1			1	1	1	1
29	Industrial paintings	18	200	1	1	1	1	1	1	1	CM	R	M	H	1	1	1	1	1	1	1
30	Brickwork, masonry and general workforce	12	150		1	1				1	CM	T	L	H	1			1	1	1	1
31	Concrete forms	28	200	1	1	1	1	1	1	1	CM	R	H	H	1	1	1	1	1	1	1
32	Steel rebars	25	120		1	1	1	1	1	1	CM	R	M	H	1			1	1	1	1
33	Machinery: general and transportation	9	1100			1				1	n/a	n/a	n/a	n/a	1				1	1	1
34	Machinery: cranes and special vehicles	22	45		1	1				1	n/a	n/a	n/a	n/a	1			1	1	1	1
35	Brickwork, masonry and general workforce	10	60			1				1	CM	T	L	H	1				1	1	1
36	Electric and electronic facilities and maintenance	14	8	1	1	1			1	1	CM	T	M	H	1	1		1	1	1	1
37	Earthwork	50	55		1	1			1	1	CM	R	L	H	1			1	1	1	1
38	Hydraulic systems	5	35		1	1				1	CM	T	L	H	1			1	1	1	1
	Total			11	35	32	9	9	29	38	-	-	-	-	35	11	18	35	38	38	38
	%	-	-	28,95	92,1	84,2	23,68	23,7	76	100	-	-	-	-	92,1	29	47	92	100	100	100

LEGEND

	Key	Description	Total	%
Intermediate product	CM	Component manufacture & sub-assembly	32	89
	NV	Non-volumetric pre-assembly	3	8
	MB	Modular building	1	3
Mode of Build	T	Traditional	13	36
	R	Rationalized	24	67
	I	Industrialized	1	3
Product standardization	H	High	15	42
	M	Medium	10	28
	L	Low	11	31
Component standardization	H	High	34	94
	M	Medium	2	6
	L	Low	0	0

Following the results presented in Table 1, concerning the 5 categories evaluated, we can state:

- **Value (adding) Proposition:** Out of the subcontractors interviewed, only 29% offer Design. 24% offer manufacturing services and almost all of them offer Project Management (92%) of their specific building trades and the majority (84%) offers services related to supply (mainly material acquisitions).
- **Place of most operations:** All of them work in the frontline. Only a few (24%) offer offsite operations. Most of them use other facilities onsite to intermediate transforming operations (76%).
- **Characteristics of intermediate products and components**: None of them works with Volumetric pre-assembly. Most of them (89%) work with component manufacture & sub-assembly, showing how much they depend of onsite operations and how far they are to have an industrialized mode of build. Confirming that, only three subcontractors work with non-volumetric pre-assembly; and only one works with modular building.
- **Processes integrating their Production Systems**: Following the Cardoso's (1996) Production System approach, Production, Procurement and Technical Assistance were identified as the core processes of the interviewed firms (100%). Managerial processes (Planning and Management of the firm) as well as Production planning where performed in almost all the interviewed (92%). Design for production was a significant 47%, being consistent the 63% of the firms who said to have rationalized modes of build. Despite of this, most of them said that they produce an unsystematic instruction of work, not a detailed Design. Confirming the initial premise, only 29% of them participate from Design (and planning) stage of the Construction Project. Is necessary to comment that even those who said they were participating from the Design phase of the Construction Project highlighted that their involvement is infrequent.
- **Modes of build**: as said in the former item, most of them (63%) work with rationalized modes of build. 34% of them work with traditional modes of build, and only one firm builds with industrialized modes. Industrialization is also related to Standardization. Notwithstanding, an important 59% work with low or medium standardization on the product they build; contrasting with 64% of subcontractors that work with medium standardized components. Complementary, 94% of them work with highly standardized components, in contrast to only 42% of them who has highly standardized products.

5. Final remarks

There are several elements to classify subcontractors' production systems. Among them we found five elements related to: 1) the work produced; 2) the components and 3) their manufacturing process, contributing to the understanding of the subcontractors' Production Systems.

Most of the interviewed firms participate only in Construction Phase. This conjuncture reflects the little period of time to them to add more value into a Construction Project.

On this sample of subcontractors we identified they were characterized by:

- Having value propositions oriented to the Project Management of their building trades, without participating on early stages of Construction Projects, in a classical Design-bid-build contractual arrangement.

- They mainly integrate they building trades onsite and they generally use as input component manufacture and sub-assembly.

- The product they build is mostly not standardized, adding uncertainties to Design definitions. Half of them have the competence to transform the Product Design in a more detailed instruction of work. Design for production is not properly used, and by the little time subcontractors have to prepare their production, prolonging rough estimating practices of work to be built.

- Even though most of them said they work with rationalized modes of build, most of them do not have a systematic and well defined process of work. Much of the organization of their operations is made by subcontractors' foremen. So the rationalization of the operations of them depends more on foremen and labor competences than on a systematic process. In despite of their good reputation in market, most of them are craft-directed organizations.

In regard of limitations on the sample studied, we identified the five elements of the subcontractor's production systems theorized early in this paper existing in the interviewed subcontractors. Even though, further analysis with bigger and more varied building trades is desirable.

5.1 Implications on subcontracting practices

Subcontractors have little participation in Design and Planning stages. The Construction Project procurement process needs to be modified, allowing subcontractors: 1) to have time to study and planning the production and manufacturing. This planning would add more value to subcontractors insofar they had enough details to reduce decisions made into the construction site; 2) to reduce risks related to present subcontractors practice to planning a roughly estimation of the work; 3) to participate in early stages of the construction project, imputing knowledge of the ´mode of build´ their building trades into the overall planning process. For them, managing these 5 elements is a way to formalize and improve their production systems.

For contractors and other subcontractors' clients, the five elements identified of subcontractors' production system could be incorporated in Design and Planning stages, as well as in tendering criteria, mainly to identify allies –and their attributions and responsibilities– in collaborative arrangements such as partnering (Smyth and Pryke, 2008).

Towards rationalization and industrialization of construction methods, subcontractors can improve their practices by developing a managerial approach on it. As discussed by Sabbatini (1989) and Cardoso (1996) industrialization of construction is an organizational process. The PDCA approach is fundamental and tools as Design for production is important to improving quality and productivity on building trades, combining the effective early use of construction knowledge and an efficient mode of build in a Construction Project and, to subcontractors' in their own building trades.

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