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Exploring Sustainability in Construction Supply Chains

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Exploring Sustainability in Construction Supply Chains

Margherita Pero, Eleonora Bottani and Barbara Bigliardi

Abstract

In EU, 50% of total energy consumption is due to activities related to the construction industry. The number of employees in this industry is increasing. In Denmark, for instance, 25% of the employees in the private sector are employed in the construction industry. Due to this strong impact on both society and environment, increasing sustainability in this sector is highly important. However, despite models for Sustainable Supply Chain Management have been proposed in literature (Seuring and Muller, 2008), still the application of these models to construction industry is understudied (Adetunji, Price and Fleming, 2008). Collaboration between all the players along the supply chain (SC) is fundamental to reach sustainability performance (Rosas, MacEdo and Camarinha-Matos, 2011; Vachon and Klassen, 2008), and the impact on sustainability performance of a product is mainly defined by its design, thus requiring also a strong integration within the company's departments. Therefore, the aim of this paper is to study the approach to sustainability used by construction companies, and to investigate whether and how an integrated approach to sustainability, both inside the company and along the SC, can be leveraged to increase the effect of sustainability practices. With this purpose, two in-depth exploratory case studies have been performed within the construction industry in Italy. Based on the preliminary results, a research framework has been developed. This serves as basis for further investigation on the relationships between contingencies (e.g., firm size and ICT

implementation level), sustainability practices, both internal to the company and along the SC, and sustainability performance.

Keywords: sustainability, supply chain, construction industry

1. Introduction

One of the most widely accepted definitions of sustainable development was provided by the World Commission on Environment and Development (1987), and states that sustainable development is the development that meets the needs of the present generations, without compromising the ability of the future generations to meet their own needs. It is currently recognized that sustainability covers three main aspects (Harris and Kennedy, 2001; Goldman and Gorham, 2006; Colla et al., 2008; Dyllick and Hockerts, 2002), i.e.:

1. The economic perspective. An economically sustainable company is able to produce goods at the minimum cost;
2. The environmental perspective. An environmentally sustainable company avoids the over-use of depleting resources or, as an alternative, privileges the use of resources which have less potential for depletion (Tsoulfas and Pappis, 2006);
3. The social perspective. A socially sustainable system should ensure, among other, fair distribution of opportunities, adequate provision of social services and gender equity (Harris, 2003).

Despite the relevance of the three pillars listed above, sustainability is mainly approached from the environmental point of view, while other perspectives, i.e. the social and economic ones, are somehow neglected (Pullman, Maloni and Carter, 2009; Hahn and Scheermesser, 2006). Some authors also point out the objective difficulty of evaluating social sustainability, because of the lack of specific and quantitative key performance indicators (Colla et al., 2008). According to this orientation, in this paper we focus on the environmental aspect of sustainability.

Achieving environmental sustainability requires exploiting sustainable practices for the provision of a product/service to the final customer, throughout the whole product life cycle, from the conception to the end-of-life. Indeed, from the environmental point of view, manufacturing and logistics activities can have a relevant impact, ranging from emissions into the environment, to the consumption of resources, up to the product's end-of-life (Rebitzer et al., 2004). In some industrial contexts, those impacts can become particularly relevant: among others, the fashion industry (Bigliardi and Bottani, 2012), the food industry (Manfredi and Vignali, 2014) and the construction industry (Bragança, Vieira and Andrade, 2014) are recognized as contexts where sustainability is a key issue.

To this latter extent, the construction industry is currently facing continual pressure to increase the sustainability of its practice. Indeed, sustainability has, in recent years, become one of the most important performance-related issues within the construction industry (Adetunji, Price and Fleming, 2008). More precisely, sustainable practices in construction are expected to minimize resource consumption, maximize resource reuse, exploit renewable and recyclable resources, protect the natural environment, create a healthy and non-toxic environment, and ensuring quality in creating the built environment (Kibert 1994; Boddy et al., 2007). Kneifel (2010) also states that the construction (housing) industry has potential to accelerate the spread of the energy crisis and to cause environmental problems, ranging from excessive energy consumption to pollution of the surrounding environment. In many countries, the construction industry is also responsible for the consumption of relevant resources. According to the European Union, the construction industry employs approx. one third of the total energy in Europe; that value increases up to 50% in other complementary activities (e.g., transport or the manufacturing of raw materials) are included in the computation (European Commission, 2009). The construction industry is also responsible for about 35% of all greenhouse emissions. Similar considerations hold for the US, where the construction industry has considerable impacts on the environment, economy,

and society: it employs approx. 30% of the raw materials and 25% of water, and produces 30% of the waste of the country (Kucukvar and Tatari, 2013). At the same time, the construction industry is a main industrial field of Europe. In Denmark, for instance, 25% of the employees in the private sector are employed by the construction industry. At European level, the construction industry (including contractors, manufacturers of construction products and professional construction services) generates almost 10% of the gross domestic product, and provides 20 million direct jobs (European Commission, 2013).

On the basis of the considerations above, in this paper we propose a framework for the analysis of sustainability practices in the construction industry. The chosen methodology of analysis is multiple case study-based research, which is used to explore the use of sustainability practices among construction companies.

The paper is organized as follows. The next section reviews the relevant literature related to sustainability in the construction industry. Section 3 details the objective of the study and the research methodology followed. In section 4, we present the results from the case studies. Section 5 summarizes the main findings of the study, discusses the main limitations and implications and proposes future research directions.

2. Literature review

The term “sustainable construction” was proposed in 1994 to describe the responsibility of the construction industry in attaining sustainability (Hill and Bowen, 1997). Hence, sustainable construction addresses the role of sustainability within the built environment and includes the ecological, social and economic factors of a construction project (Kibert, 2008), according to the three main pillars of sustainability mentioned previously. Nonetheless, other authors (e.g., Hill and Bowen, 1997) claim that there are four pillars of sustainability for the construction industry, namely: social, economic,

biophysical and technical. The biophysical pillar covers the issues related to atmosphere, land, underground resources, marine environment, flora and fauna, while the technical pillar reflects the quality of the building structure.

In a recent conceptual paper, by reviewing the relevant literature on construction industry, Agyekum-Mensah, Knight and Coffey (2012) propose a 4Es (i.e., Economic, Effectiveness, Efficiency and Ethics) and 4 poles (Economic, Social, Environmental and Technology) model of sustainability in construction. According to the authors, the first pole (“economics”) suggests that the construction industry should be able to sustain itself financially, avoiding cost overruns. From the “social” point of view, the construction industry is a labor intensive industry and a main industry field of Europe. Therefore, its social function is to increase labor opportunity and reduce poverty. As regards the “environment”, the construction industry is expected to design environmental friendly buildings and structures. Indeed, an excessive use of resources is critical for the ecosystem not only because of the depletion of resources, but also because of other concerns, such as the destruction and long-term change of natural habitats and distortions of the potable water supply (Bringezu, 2002). Finally, the “technology” for a particular construction project should be chosen by the project management team through their techno-socio-economic environmental assessment.

The construction industry grounds on individual processes such as design, energy consumption and materials in achieving sustainability. However, all of these aspects are part of the project management process. From the above description, therefore, it is clear that an efficient project management plays a crucial role in improving sustainability of the construction industry. In the case of the construction industry, project management activities spans from pre-construction to post construction, according to the scheme in Figure 1 (adapted from Caron, 2009). More precisely, following a chronological scale, the main operating processes of a construction project include: (1) the design of the product (e.g., building); (2) the procurement of raw materials and components

for the construction; (3) the construction and assembly activities; (4) the first start and testing of the product; (5) its activity; and (6) its end-of-life.

An effective project management strategy has potentials to significantly improve the sustainability of the construction project. As an example, a proper management of the construction project can decrease the current cost of the construction industry, the related overruns and delays. To this extent, literature suggests some sustainability practices that can be adopted at the various steps of the construction project, taking into account not only the construction company but also its upstream players, which also contribute to sustainability (Bringezu, 2002). A summary of some of those practices is proposed in Table 1.

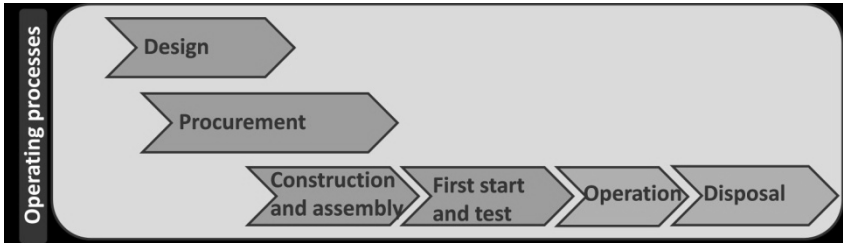


Fig 1: operating processes of a construction project

Project's Phase	Sustainability practices and tools
Design	Lifecycle product/process design and costing; design for reuse and disassembly, life cycle assessment (Beamon, 2008; Carter and Rogers, 2008; Beamon, 1999; Agyekum-Mensah, Knight and Coffey, 2012; Adetunji, Price and Fleming, 2008; Tan, Shen and Yao, 2011) Availability of information related to the energy efficiency of the construction (Rezgui, Wilson and Li, 2010) Development of specifications for suppliers describing the requirements in terms of environmental impact (Azevedo et al., 2011; Zhu et al. 2008)

Project's Phase	Sustainability practices and tools
Procurement	<p>Selection and evaluation of suppliers based on sustainability criteria (Vachon and Klassen, 2006; Verdecho, 2010; Sarkis, Meade and Presley, 2012)</p> <p>Use of environmental certifications (Zhu et al. 2008)</p> <p>Recruitment of resident employees and procurement of local materials, to enhance the local economy (Adetunji, Price and Fleming, 2008)</p> <p>Use of environmental efficient transport policies (Carter and Rogers, 2008; Adetunji, Price and Fleming, 2008)</p> <p>Use of environmental friendly raw materials (Zhu et al. 2008)</p> <p>Use of decentralized distribution systems, with shared stock capacity and transport activities (Beamon, 2008)</p> <p>Collaborations with suppliers to decrease the environmental impact of the final product (Azevedo et al., 2011)</p>
Construction and assembly	<p>Increasing the company's innovation and technological capabilities, to increase the sustainability of the construction process and the final product (Tan, Shen and Yao, 2011)</p> <p>Minimizing emissions, waste, energy and water consumption during the construction (Adetunji, Price and Fleming, 2008)</p> <p>Improving health and safety of the workplace (Carter and Rogers, 2008)</p> <p>Training of employees (Adetunji, Price and Fleming, 2008)</p> <p>Ensuring fair conditions for employees (Adetunji, Price and Fleming, 2008)</p> <p>Using energy from residual or alternative fuels instead of energy from fossil fuels (Beamon, 2008)</p>
First start and test	<p>Certification of the sustainability practices (Adetunji et al., 2008)</p>

Tab. 1: sustainability practices as a function of the project phase and related literature

At the same time, the adoption of sustainability practices could be difficult to a construction company, for a number of reasons. First, the know-how related to sustainability practices is often limited to the single company and does not cover the whole construction supply chain, which is a requirement to be fully sustainable (Vachon and Klassen, 2006; 2008). Also, it is often unlikely that a construction company owns a perfect knowledge of the sustainability practices of this context, because the related know-how is somehow fragmented and difficult to access (Rezgui, Wilson and Li, 2010; Adetunji, Price and Fleming, 2008). A further main barrier is the cost of sustainability practices: it often happens that practices that are sustainable from the environmental point of view are not profitable from the economic perspective (Carter and Rogers, 2008). For instance, certifications of compliance to sustainability standards, released by known authorities, may have a significant cost (Adetunji, Price and Fleming, 2008). The company's position inside the supply chain and its (consequent) bargaining power could be a further barrier to the implementation of sustainability practices (Azzone and Noci, 1998; Adetunji, Price and Fleming, 2008).

The above overview suggests that there are several studies related to the sustainability of the construction industry. However, the current literature leaves some open questions. Specifically:

- most of the research focuses only on the environmental facet of sustainability in the construction industry, while other perspectives (e.g., the social or economic) are relatively new and less explored (Bringezu, 2002);
- there is still no general consensus on the definition of sustainability and its relationship with the construction industry; consequently, there is no consensus on which aspects should be considered in evaluating the sustainability of a company that operates in this sector and the output it produces (Matar, Georgy and Abou-Zeid, 2010; Pearce and Vanegas, 2002);

- limited attention is paid to the management of collaborative, non-core activities such as the management of sustainable practices (Vachon and Klassen, 2006; 2008).

Starting from those gaps, this study focuses on the analysis of sustainability in the construction supply chain and tries to contribute to the literature by developing a framework to explore this topic inside the selected industrial field.

3. Objectives and methodology

Based on the outcomes from the literature review presented in the previous section, and in particular moving from the research gaps identified at the end of the same section, the main objective of our study is to explore the use of sustainability practices among construction companies. Specifically, we provide evidences from the field, by analyzing two real examples of construction companies that adopt sustainable practices. Companies were selected among the eight companies participating to the "Responsible Building" project, sponsored by the local association of the construction companies, whose objective is to spread sustainable practices among the companies in the construction industry. In order to reach the objective stated above, we adopted a methodology that was a combination of literature analysis and case study-based research. At first, a review of the specific bibliography was performed to identify the main sustainability practices adopted by construction companies, their drivers and barriers, the contingent factors as well as the main performance indicators to be used in the industry investigated.

As the second step of the research, multiple case studies were developed. The case studies had the primary aim of understanding the use of sustainability practices among construction companies. They were carried out with a series of semi-structured interviews, with the manager of each company, over a three-week period in March 2014. Interviewees were given a brief introduction about the study, its aim, as well as the questions contained in the questionnaire used as guidelines for the interviews. When required, an overview of the concepts

investigated was provided. The questionnaire included four sections: the first one aimed at collecting general information about the company and the interviewee, while the second one contained questions on the SC configuration as well as the internal organization of the company. The third and fourth sections aimed at investigating which sustainability practices, among those identified in the literature review, are adopted in real contexts and the way they are managed. The same analysis was extended also to sustainability drivers and barriers.

4. Results from the case studies

This section presents the main evidences from the case studies. In this study, each kind of project that is managed differently from the others in the same company, i.e. the role of the interviewed company changes, is taken as a unit of analysis. Therefore, one and three units of analysis were identified in company A and B, respectively:

- For company A:
 - all construction projects of the company
- For company B:
 - "B-Subcontractor": All those projects when company B is involved mainly as general contractor managing the building phase (in yard);
 - "B-Project finance": All those projects when company B is involved as part of the financing consortium; and
 - "B-Self-promoted": All those projects where company B manages all the phases directly, being itself the commissioning body.

For each unit of analysis, the distinguishing features of the phases as well as the sustainability practices used were investigated.

4.1 Sustainability: areas of interest, drivers and barriers

The two companies analyzed differ in terms of size and the area of sustainability which they are more interested in. Specifically, company A is a

small enterprise (about 15 employees – for approx. 10 M Euros of revenues in 2012), mainly concerned with the environmental facet of sustainability. Conversely, company B is specialized in the development of large real estate projects and the redevelopment of complex areas. The company's revenue in 2012 accounted for approx. 530 M Euros. Company B is strongly committed to sustainability, both under the environmental and social responsibility perspectives. In fact, the company participates in projects for improving the Corporate Social Responsibility of construction companies, and asked its suppliers to implement (voluntarily) monitoring systems for improving workers' safety in the yard. Similar drivers push both companies to sustainability, i.e. pressure from customers and competitors' moves. In fact, both companies perceive sustainability as a competitive tool to gain market shares, since both of them claim that customers are more and more interested in sustainability and that competitors are becoming more sustainable too. "Sustainability of the building is a must-to-have for the customer", states one of the interviewee in company A, whereas company B is mostly concerned with sustainability especially for those projects that they manage entirely, (i.e. the "B-self promoted" unit of analysis). Managers, who in both companies are strongly committed to sustainability (as demonstrated by the fact that both companies are involved in the abovementioned "Responsible building" project), are actively supporting the implementation of sustainability practices. Interestingly, both companies state that the pressures of suppliers or public opinion is not enough strong to become a real driver to move companies to sustainability. Despite the similarities, in company A, according to the interviewee, sustainability is still in some cases pursued by the company with the aim to comply with law requirements and to reduce the risk of penalties; this does not apply for company B. As far as the barriers are concerned, both companies claim that the whole industry seems still not to completely understand the importance of sustainability, also - among the others - because sustainability is perceived to increase materials and procurement costs, which is not well balanced by the increase in revenues, at least in the short term. In company B, this perception

has led, for those projects not completely controlled by company B ("B-Subcontractor" and "B-Project finance"), to a limited management commitment to sustainability, which was a barrier to the implementation of sustainability practices.

4.2 Projects phases

At first, we investigated how each phase of the construction project is managed inside the two companies. We noticed that, although the activities performed within each phase were quite similar, the extent to which these activities were performed by resources internal to the interviewed company (i.e., the level of ownership of the phase) was different depending on the unit of analysis. Details can be found in the following sub-sections.

4.2.1 Company A - project phases

Company A operates as general contractor, but has different levels of ownership on the different phases of the projects (see figure 2). A typical construction project is divided into three phases: Design Phase, i.e. the activities related to the definition of the specifications of the project; Procurement Phase, i.e. the activities related to the definition of the suppliers of the materials to be used in the project; Building Phase, i.e. the activities related to the actual building in the yard. Company A controls the whole design phase, possibly supported by external designers whenever the number of internal designers is not sufficient. The same applies for the procurement phase, where suppliers are selected by company A among the ones already pre-selected and available in the suppliers' base of the company. Finally, other companies, under the supervision of company A, carry out the building phase completely.

		Phase		
		Design	Procurement	Building
Level of ownership	High	A	A	B-Self promoted
		B-Self promoted	B-Self promoted	B-Subcontracting B-Project finance
	Medium	B-Project finance		
	Low	B-Subcontracting	B-Subcontracting B-Project finance	A

Fig. 2: Level of ownership of the project phases for all the units of analysis

4.3 Company B - project phases

For company B, the level of ownership of the project phases depends on the kind of project analyzed, i.e. on the unit of analysis. In particular, all the phases of "B-Self promoted" projects are managed directly and entirely by company B, whereas the customer strongly influences the design as well as the procurement activities in the case of "B-Subcontracting" and "B-Project-finance". As for the design, in "B-project finance", being company B one of the financing partners, it can influence the design of the building to some extent. Conversely, when "B-Subcontracting" is at stake, company B has limited possibility to influence the final design of the building. In the case of procurement, instead, in both situations the customer pre-selects the suppliers in the procurement phase.

4.4 Sustainability practices

In this section, we present the results related to the approach to sustainability shown by the companies, as well as to the sustainability practices used by the interviewed companies in the analyzed units of analysis.

4.4.1 Company A - sustainability practices

Due to the small size of the company, there are no departments expressively dedicated to the project design and purchasing steps respectively. However, all along the project lifecycle, meetings involving internal and external designers, the purchasing manager and the suppliers are frequently held to discuss on material choice and technical solutions. Similarly, there is not a company's manager dedicated to sustainability. All the people involved know the company policy for sustainability and must apply it. Table 2 lists the practices used in company A. It is noteworthy that a practice can be applied with different approaches. For instance, practices can be applied only within the walls of the company (internal focus) or can be extended to the suppliers. In this case, some practices are implemented by leveraging on the collaboration with the other partners (collaborative approach), whereas others are used to control the work performed by other partners (control focus).

4.4.2 Company B - sustainability practices

In company B, there is not a specific role appointed to sustainability, although there is a person managing quality and environmental management system (in line with the ISO 9001-14001 standards). In the case of "B-self promoted", both the proposal manager, from the sales department, and the project manager are strongly concerned with sustainability.

According to the interviewed project manager of company B, "the decision not to outsource building phase is one of the main elements that determined the success of company B: aligning the objectives of these two roles, while keeping the complete control of the building phase, allows to obtain a building that is, at the same time, the most possible sustainable and attractive for the customer".

In Table 3, the practices used in company B can be found.

Phase	Practices	Description
Design	Life Cycle Assessment / Eco-Design	The impact of design decisions on environmental performance of the product along the product lifecycle are assessed involving both internal resources and supplier (collaborative approach)
	Training	Internal resources are trained to increase their knowledge in the environmental impact of building (internal focus)
	Rules and procedures	Rules and procedures for eco-design are provided to external designers, then the output provided by these designers are evaluated against the provided rules (control focus)
Procurement	Vendor lists	Company A in collaboration with other companies in the construction industry is developing a list of suppliers certified to be compliant with environmental and social issue. This list will be available in database shared among different companies (collaborative approach)
	Local sourcing	Suppliers are located nearby

Tab. 2: Sustainability practices used by unit of analysis A

Phase	Unit of analysis	Practices	Description
Design	B-Self promoted	Life Cycle Assessment/ Eco-Design	The impact of design decisions on environmental performance of the product along the product lifecycle are assessed involving both internal resources and supplier (collaborative approach)

Phase	Unit of analysis	Practices	Description
		Suppliers involvement	Suppliers are involved in the early phases of design to identify innovative and sustainable solutions (collaborative approach)
	B-Project finance	Rules and procedures for designers	Rules and procedures for eco-design are provided to the designers of company B. This happens only when the customer is interested in eco-design (control focus)
	B - Subcontracting	Not Applicable	
Procurement		Vendor selection	Suppliers are selected using sustainability performance indicators (control focus)
	B-Self promoted	Suppliers monitoring	Environmental and social performance of the suppliers are assessed along the project to control the suppliers as well as to support vendor selection for the future projects (control focus)
	B-Project finance	Not applicable	Suppliers are selected by the customer with no involvement of company B.
	B - Subcontracting	Not applicable	

Phase	Unit of analysis	Practices	Description
Building	B-Self promoted	Awareness and monitoring of workers' safety in yard	Training on how to improve safety of the workers in yard, risk mapping and definition of prevention and protection measures, for both internal and external resources. (collaborative approach)
	B-Project finance		
	B-Subcontracting		

Tab. 3: sustainability practices used by company B

5. Discussion and future research

Starting from the results described in the previous sections, a series of conclusions may be drawn. Literature has already discussed that there are drivers and barriers to the implementation of sustainability practices. Results of our case studies confirm this. However, despite the two companies are exposed to similar drivers and barriers, the practices adopted in each unit of analysis are different. Therefore, a more complex model for interpreting these outcomes is needed. Based on our results, the level of ownership might play a role in the relationship between drivers/barriers and sustainability practices adopted. In fact, in those cases when a higher control is used over the phases, companies tend to apply more sophisticated sustainability practices, involving with a collaborative approach - when applicable - the network of suppliers, vice versa, when they have low ownership of the phase, despite the importance of the drivers and barriers is the same. Moreover, certain practices, such as the monitoring of suppliers' performance all along project phase or the use of vendor lists, require resources that small companies might not have.

Thus, on the basis of these considerations, we can derive a framework of relationship and ties in place between sustainability practices and its theoretical antecedents as depicted in Figure 3.

As a further result, based both on the literature review and on the information collected from the interviews, an operationalization of the constructs that constitute such a framework can be provided. As far as the drivers are concerned, we propose as factors to measure this construct, the following ones: pressure from customers, competitors' moves, compliance with laws requirements, risk management, pressures of suppliers, and pressure from public opinion. As for the barriers, this construct may be seen as composed of the following factors: lack of knowledge about the concept of sustainability, increase in the cost of materials and procurement as a consequence of

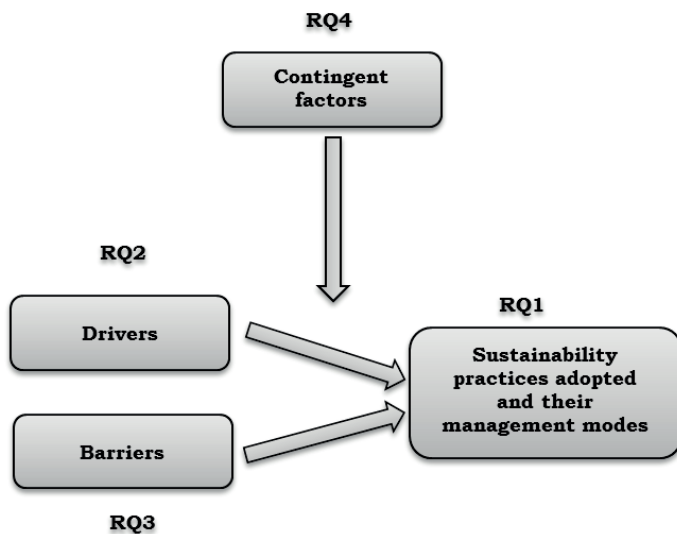


Fig. 3: The research framework proposed

adopting sustainability practices, and low management commitment. We are aware that some of these factors have not resulted to be important in our analysis (e.g., pressures of suppliers or public opinion among the drivers), and also that some of these factors have resulted to be important only for small companies (e.g. better risk management among the drivers). The originality of

our work consists in the introduction of the construct "Contingent factors" as control variable: by "Contingent factors" we mean all those factors that can determine the adoption of a given sustainability practice instead of another one. In other words, we expect that, depending on the company's size, on the control on each phase of a construction project, as well as on the level of ownership, the relationship among the other constructs in the framework and the sustainability practice adopted may vary.

Finally, from the research framework depicted in figure 3 it is possible to derive four research questions (RQs) that represent the basis for the future (ongoing) research:

RQ1: Which sustainability practices are adopted by companies operating in the construction industry and how are they managed?

RQ2: Which are the main drivers for the adoption of these practices and their management?

RQ3: Which are the main barriers to their adoption?

RQ4: How contingent factors influence the adoption of sustainability practices?

The results of the present study may have a number of implications for managers in the construction industry. For instance, they may suggest that the types of sustainability practices adopted depend on the SC configuration as well as from the level of sustainability. We recognize as well a main limitation of our study, which refers to the methodology adopted, and, specifically, to the number of case studies. A future development of our research will consider a larger sample of companies belonging to the construction industry, thus allowing the generalization of our results, which was not possible at this stage of the research. Indeed, the outcome of the study, that is the research framework developed, shall be used in order to test the relationships between the constructs hypothesized in the construction industry as well as in several other industries. Moreover, the same framework shall be further improved by considering also the impact that the adoption of sustainability practices may have on the performance of a company, in terms of economic performance, environmental performance and social performance.

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