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Title: Costing Sustainable Capital Projects: The Human Factor
Intended Category: Embedding Sustainability

Abstract: How do constructors and their associated supply chain establish the cost of green projects and systems, and what can it tell us about how policy and the project delivery process/environment should be changed to reduce this key barrier to sustainability? This paper provides an overview of the challenges faced by contractors, subcontractors, and their supply chains in costing green vs. conventional projects, at various stages of the project delivery process. The primary aim of the paper is to lay the groundwork for identifying key leverage points in the process where relevant data can be introduced and actions taken to influence cost. With this information, project stakeholders can better understand what influences the cost margin associated with green projects, thereby taking the first step toward controlling project cost for competitive advantage in the market and increasing the likelihood of adoption of sustainable technologies and strategies in capital projects.

The First Cost Barrier to Sustainability in Capital Projects

Despite motivation to improve the sustainability of capital construction projects, stakeholder perceptions of the initial cost of such projects are a barrier to implementation (Klotz et al. 2007a; Lapinski et al. 2005, 2006; Morris 2007; Pearce 2008a; Pearce & Fischer 2002; Syphers et al. 2003; Wilkinson & Reed 2007; Williams & Dair 2007; Wilson & Tagaza 2006). Multiple studies of the actual first costs associated with green projects have found the margin between green and conventional projects to be surprisingly small, no more than 2-3% of total installed cost for the lowest levels of LEED certification. In one study, the average premium from 33 green buildings across the U.S. compared to conventional designs for those same buildings was slightly less than 2%, or \$3–5/ft^2, thought to be because of increased architectural and engineering design time, modeling costs and time necessary to integrate green building strategies into projects (Kats 2003). A range of other studies have found results ranging from an average of less than 1% cost premium for projects at the lowest level of certification to 7% or more for buildings at the higher levels of certification (Table 1).

Despite these quantitative studies, a common perception exists that green buildings cost significantly more than their traditional counterparts. A recent study of 87 leading construction companies in the US asked what level of cost premium respondents believed green buildings would carry compared to conventional construction (Ahn & Pearce 2007). 35% of respondents believed that the cost premium of green building is 5% to 10% compared to conventional construction, and another 27% of the respondents believed the cost premium would be greater than 10%. Less than 1% of the respondents indicated a belief that green building costs the same or less than conventional construction (Figure 1). These responses demonstrate that the construction industry still believes that green building costs significantly more than conventional construction, despite the growing body of evidence to the contrary (Bartlett & Howard 2000). What is responsible for this divergence, and how does it impact the implementation of sustainability in the capital projects industry?

Table 1: Green Project Cost Studies – Actual Margin

Study	**Cost Premium**			
	Certified	Silver	Gold	Platinum
Kats 2003 8-18-6-1	0.66%	2.11%	1.82%	6.50%
Kats 2004 8-21-9-2	0.66%	1.91%	2.23%	6.80%
Steven Winter 2004	0.65%	3.29%	7.63%	-
1 each of new/renov	1.9%	3.9%	7.9%	-
Kats 2006 4-8-6-0	1.17%	1.03%	2.15%	-
Nilson 2005 1-1			0.82% & 1.56%	

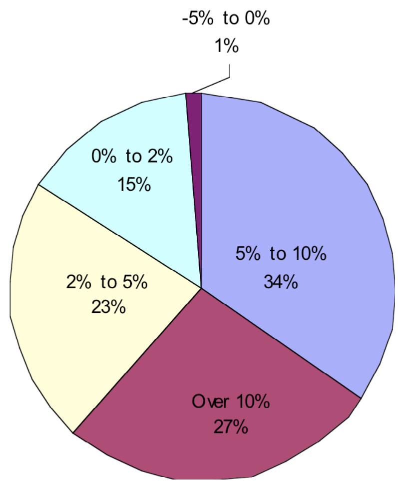

Figure 1: Contractor Perceptions of Green Cost Margin (Ahn & Pearce 2007)

Point of Departure: The Costs of Building Green from a Constructor Standpoint

From the perspective of construction as a production process, contractors and subcontractors represent the general and specialized units within the process that accomplish the actual production of the desired product (Gil et al. 2000b). They are the critical mechanism by which the aim of the production process is realized as well as the source of actual project cost (Errasti et al. 2007). With design-build procurement and pre-construction services on the rise, these players also have an important role in the early phases of capital projects (Horman et al. 2006). Their input has potential to shape how projects are realized in multiple ways (Errasti et al. 2007), including influencing planning and design decisions that have cost implications for the project. Together with the supply chain that provides materials and products for the production process, these actors constitute the constructor subsystem within the larger socio-enviro-technical (S-E-T) system that comprises a capital project (Rohracher 2001).

The literature on risk also provides insight as to how contractors approach the task of pricing projects with unfamiliar components or unusual contextual conditions (e.g., Baloi & Price 2003; Birnie & Yates 1991; Chan & Au 2007, 2009; Chapman et al. 2000; Cooper et al. 1985; Ho & Liu 2003; Neufville & King 1991), and the literature on construction quality includes approaches for quantifying the costs associated with difficult to quantify attributes such as changes in project quality (Aoieong et al. 2002; Hall & Tomkins 2001). However, to date, little of this "bottom up" understanding of project cost has been extended to address the unique qualities of green projects, including tightly coupled designs and multifunction materials and systems (Riley et al. 2003; Rohracher 2001), procurement of unusual products with limited sources (Klotz et al. 2007a; Pulaski et al. 2003; Syphers et al. 2003), existence of incentives and resources not available to other projects (Grosskopf & Kibert 2006; Pearce 2008a; Rohracher 2001), requirements for additional information and documentation (Lapinski et al. 2005, 2006; Pulaski et al. 2003), and greater involvement of later stakeholders in earlier project phases along with greater integration of their input (Cole 2000; Gil et al. 2000a; Matthews et al. 1996; Pulaski & Horman 2005c; Pulaski et al. 2006; Reed & Gordon 2000; Rohracher 2001). While some research has been done to quantify incremental costs for project design (Larsson & Clark 2000; Enermodal Engineering 2006), costs associated with incremental changes to construction practice remain unexplored.

Existing research on the first cost of green projects has focused for the most part on the development of descriptive studies of total installed cost (e.g., Kats 2003; Kats et al. 2003; Kats 2006; Matthiessen & Morris 2004a, b, 2007), and case-derived explanations of cost premiums with regard to individual LEED credits (USDHHS 2006; Enermodal Engineering

2006; Nilson 2005; Stegall & Dzombak 2004; SWA 2004; Weber & Kalidas 2004) or the soft costs of LEED Certification (Enermodal Engineering 2006; Northbridge 2003). One study (Mogge 2004) developed estimated premiums on an ordinal scale for various sustainability-related project features based on polling expert groups to determine level of cost influence of these tactics. However, Mogge's study did not attempt to link cost influence with specific project conditions, and thus his cost influence correlations are very general. Other ordinal classifications by cost of sustainability best practices also exist in the literature (Tinker et al. 2006; Wilson 1999), but being able to develop context-specific estimates of the cost impact of various features would require an understanding of how those practices would be *implemented* for a particular project along with the cost drivers associated with each practice and is thought by some practitioners to be difficult or impossible to determine (Morris 2007). The popular literature has drawn some conclusions about what the project-specific cost drivers for green projects might be, but the focus has been largely on design-related drivers such as experience of the project team with developing LEED documentation (Yudelson & Fedrizzi 2007; Korkmaz et al. 2009; Syphers et al. 2003). Much of the work by Bilec & Ries (2007) and Carpenter (2005) on the correlation between project delivery method and green design also falls into this category, although some aspects deal specifically with constructors.

More generalized costing tools exist for green projects such as US Naval Facilities Command's DD 1391 tool (NAVFAC 2008) for preparing programming documents for new projects that will meet its LEED policy requirements, or the R.S. Means *Green Building Project Planning and Cost Estimating* guide and accompanying CostWorks software (R.S. Means 2006). However, the normative representation of costs in these tools does not reflect the perceived risks associated by later adopters with green projects that is reflected in the green cost margin (Morris 2007; Syphers et al. 2003), nor do they account for some of the context-specific, cost-influencing factors such as labor and material availability, market conditions, or special procurement or code requirements that may lead to higher cost margins (R.S. Means 2006). Finally, both the NAVFAC and CostWorks tools acknowledge in their instructions the need to account for overlapping or cascading effects of green features on other aspects of the facility, but neither provides a mechanism for doing so, nor do they offer insight into the potential complementarities of design that can influence cost from a constructor standpoint such as the effects of the building design on equipment selection, safety requirements, or materials procurement.

Roles and Responsibilities for Cost in Green Projects

Both the academic and popular literature tend to put the burden for first cost reduction on the designers of a project by advocating strategies such as integrated design, which offsets investments in one building system with savings in another (e.g., Hydes & Creech 2000; Magent et al. 2005; Reed & Gordon 2001; Hawken et al. 1999). This aligns with conventional wisdom, often expressed as the classic S-curve of ability to influence cost vs. time (Reed & Gordon 2000). Although integration and value enhancement tactics and their associated risks have been investigated by researchers in the lean construction and partnering/supply chain alliance domains (e.g., Bae & Kim 2008; Castro et al. 2008; Green 1994; Lapinski et al. 2005, 2006; Riley et al. 2003, 2005; Pulaski & Horman 2005a, b), whether or how this integration is accounted for in the work planning/estimating processes *inside* the constructor subsystem has not been widely studied, nor is there detailed understanding of how contractors presently approach the task of developing work breakdowns for green projects or identifying opportunities for integration from a procurement/construction standpoint (Demaid & Quintas 2006), although the process has been acknowledged in the general literature as widely variable (Diamant 1988; Dulaimi et al. 2002).

An owner- or designer-driven problem frame gives most of the power for influencing project cost to early project stakeholders, with the constructor subsystem often representing a "black box" that will determine a price for whatever design configuration is provided (Taylor & Wilkie 2008). Market forces are presumed to generate the best possible price for the product based on market conditions (Skitmore & Smyth 2007; Skitmore et al. 2006). For liability reasons, much of the detailed information about *why* a price quote is what it is remains opaque (or "behind the veil") to the stakeholder requesting it (Tirolo 1999). The nuances of so-called "operative details" – means, methods, and decisions about product selection and procurement – are, in general, deliberately avoided by other stakeholders to avoid claims of damage under the legal doctrine of retained control. The focus on the owner and designer in the current body of research keeps the *why* of the green cost margin behind the constructor's veil, pierced only in rare cases through detailed case studies of specific projects and the specific features employed in the unique context of those cases (e.g., Weber & Kalidas 2004; Klotz et al. 2007b; Nilson 2005). The few studies that have pursued this understanding have been mostly limited to one layer of investigation (e.g., general contractor interviews) based on retrospective data, and have not attempted to pierce the veils of other related players such as subcontractors and suppliers. This problem, which also pervades other studies of constructor systems (Dainty et al. 2001), persists despite evidence showing that better relationships among contractors, subcontractors, and suppliers can have a significant impact on project costs (Khalfan et al. 2006; Matthews et al. 1996, 2000; Proverbs & Holt 2000; Uher & Runeson 1985). The studies that *have* investigated these relationships (e.g., Hinze & Tracey 1994; Dainty et al. 2001) reveal a widely variable, complex set of changing and evolving relationships among players that combine to result in unique effects on the cost of each project. A generalized understanding of construction-based cost drivers resulting from actor-network interactions and lead to the green cost margin remains to be developed.

Research conducted from an owner- or designer-driven perspective also fails to take into account the translation of building features into work packages and processes that happens when a constructor prices a project (Matar et al. 2008). For instance, a simple product substitution may be easy enough to evaluate in terms of a cost differential, but more complex, integrated strategies such as building-integrated photovoltaics (Eiffert 2003; Margolis & Zuboy 2006) or green roofs (Hendricks & Calkins 2006) become harder to separate when they may span multiple subcontractors whose work also includes other scope. This can lead to a translation problem, depicted in Figure 2 for one possible scenario. While partnering and supply chain alliances might seem to mitigate this problem from an owner perspective, other parts of the supply chain such as subcontractors and suppliers may respond suspiciously (Dainty et al. 2001; Eriksson et al. 2007; Errasti et al. 2007). The problem only becomes more complex when the interactive effects of implementing multiple building features at once are taken into account (Pearce 2003). Moreover, even simple product substitutions have the potential to introduce costs that are not accounted for in normative cost models of green systems, such as unusual shipping costs for products with only a few manufacturers (Malin 2000; R.S. Means 2006).

The Green Cost Margin

The potential influence of these multiple layers is shown in Figure 3. Each time a request is made that involves stepping out of common practice, the risks associated with the request may be absorbed by adding a contingency cost margin that is passed up the hierarchy. Since many of these contingencies are included on a percentage basis, each margin added at a lower level has cascading effects for other stakeholders who incorporate that price as part of their price. The green cost margin may also include other direct costs besides contingencies, such as known transport costs for materials outside the typical supply chain, costs for unusually-sized systems specified as a result of integrated design, or the cost of higher quality materials and systems (Bordass 2000). For production entities such as contractors and subcontractors, margins may include factors for learning curves, training, or other novel costs of delivery itself (Akintoye 2000; Atkinson et al. 2006). Each of these costs is context-dependent and/or specific to the stakeholders involved in a particular project. While these types of costs can also be associated with construction innovations in general, the tightly coupled design of green projects along with enhanced information tracking requirements and greater participation prior to construction makes them especially acute in these types of projects.

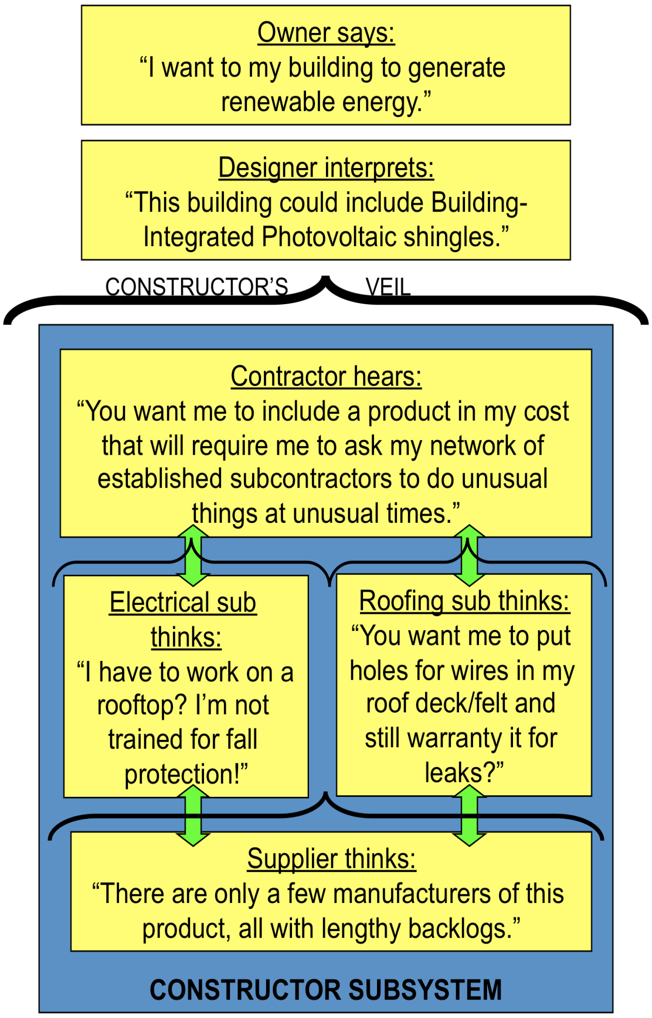

Figure 2: Inter-stakeholder Translation Problem

The owner-driven focus of current research also has the potential to introduce bias with regard to the subset of the population of designers and constructors being studied. Since the owner has the power to influence selection of the project team, focusing on early adopting owners of green projects may systematically select a more innovative subset of the population of contractors (and subsequently subcontractors) who have different characteristics than the population at large. The selection of parties to participate in a capital project is non-deterministic and influenced by a variety of factors (Keysar & Pearce 2007). Out of necessity or choice, nearly all the studies conducted so far have focused on the innovator or early adopter classes of the owner population (Korkmaz et al.2009).

As pointed out by Moore (1999) and others, the characteristics of these adopter classes are markedly different than subsequent classes of early majority, late majority, and laggards. For instance, later adopter categories tend to favor technologies and practices that have been successfully demonstrated on peer projects, either within their own portfolios or within the portfolios of similar owners (Pearce 2003; Pearce et al. 2005; Rogers 2003; Toole 1998; Koebel 1999; Koebel et al. 2003; Koebel 2004). This also has implications for the types and structure of information that may be most effective in providing training to motivate these later adopter classes, which comprise the majority of the population and therefore represent the most significant potential for transformational change of the industry.

Sustainability as Innovation: A Construction Perspective

Given the increasing rate with which green principles and practices have been adopted by industry leaders (USGBC 2009; Ahn & Pearce 2009), diffusion of innovation theory provides a key theoretical underpinning for this work, in particular the attributes of innovations and characteristics of adopters which influence whether or not an innovation is adopted and/or routinized in a specific instance (Klein & Sorra 1996; Rogers 2003; Langar 2008). Considered from the standpoint of contractors and subcontractors, sustainability as an innovation compares rather poorly to the status quo, especially for later adopter categories who miss the opportunity to use sustainability expertise as a market differentiator.

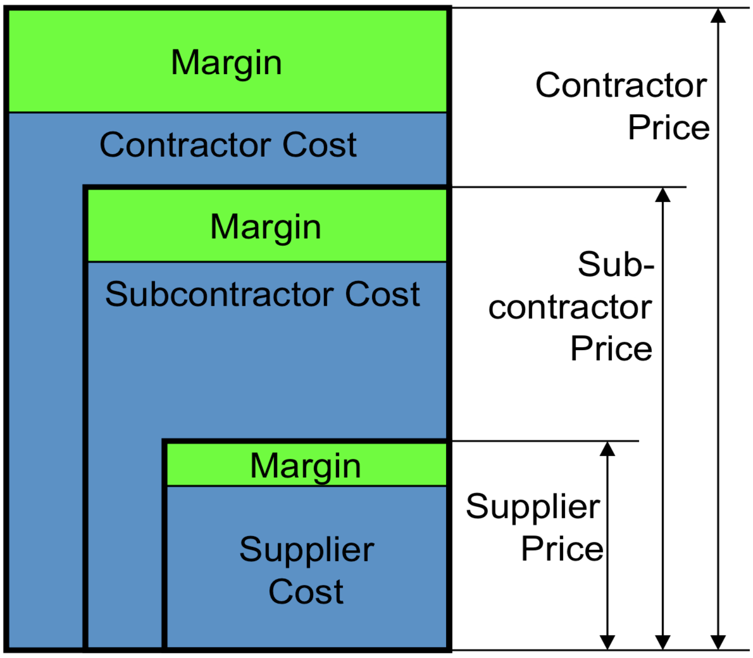

Figure 3: Cascading Green Cost Margins

In terms of relative advantage, the benefits of sustainable construction tend to accrue to other stakeholders or even non-stakeholders, particularly the owners and occupants of the facility and future generations who may benefit from reduced environmental impacts and resource consumption (Taylor & Wilkie 2008). These benefits may also be difficult for the constructor to see since they are typically spatially and temporally distant from decisions made during construction (Gardner & Stern 1996; Khalfan 2006), thereby reflecting poor observability. From the standpoint of trialability, integrated design and delivery tactics require contractors to "jump in with both feet" rather than being able to try sustainability concepts and practices at their own pace (Lapinski et al. 2005; Horman et al. 2006). The use of new technologies and products may require deviation from established subcontractor and supplier networks, thereby reflecting poor compatibility with contractor assets that traditionally afford a source of competitive advantage (Kale & Arditi 2001).Finally, all of these factors combined with the demands of extensive new documentation, product qualification requirements, and additional general requirements such as waste management, indoor air quality best practices, and commissioning lead to a tremendous disadvantage in terms of complexity (Klotz et al. 2007a). Other than altruism, the only obvious drivers for sustainability adoption by later adopting constructors may be compliance with policy or owner requirements, particularly with competitive advantage and potential cost savings not yet well-established in the market (Grosskopf & Kibert 2006) or even well-understood by owners (Lapinski et al. 2005). From this perspective, it should come as no surprise that members of the constructor subsystem have not universally embraced sustainability (Panzano et al. 2004).

Of all the attributes of construction innovations that affect their adoption, relative advantage in terms of cost is thought to be the most influential (Gambatese 2007; Holmen 2001; Toole 1994). It is also directly correlated to the green cost margin in that the margin represents the *difference* between the innovation under consideration and the status quo, which is the reference point against which relative advantage is judged. From the owner's standpoint, the green cost margin represents the net cost that must be subtracted from potential benefits of an innovation in order to judge its relative advantage. The margin is also a determinant of relative advantage to the contractor: higher margins reflect the potential for higher profit from a project, but they also increase the risk that the project will not materialize at all, particularly in a competitive bid situation. As a factor directly relevant to both contractor's and owner's perception of the relative advantage of a green project vs. a conventional project, the green cost margin is well worth understanding in more detail.

Interventions for Increasing Diffusion and Adoption of Sustainability in Capital Projects

Diffusion of innovation theory also offers a framework for understanding what types of interventions could be undertaken to reduce barriers to innovation, and what types of evidence may be most useful in encouraging more widespread adoption (Rohracher 2001). For instance, Toole (1998) found a statistically significant difference in the *sources* of information on which adopters in the homebuilding industry relied in their early adoption decisions of innovations. Specifically, builders more apt to adopt high uncertainty innovations tended to rely on other builders, in-house testing, and subcontractors as important sources of information about potential innovations. In contrast, builders apt to adopt low uncertainty innovations relied more heavily on architects, homeowners, manufacturers, and subcontractors as sources for information related to potential innovations (ibid.). These findings support conclusions from the more general diffusion of innovation literature that while both information from external sources and experience can act as antecedents to innovation adoption (e.g., Gluch et al. 2009), scientific evidence may be less effective than other types of evidence such as peer experiences in motivating adoption, particularly for later adopter classes (Panzano et al. 2004; Abrahamson 1991; Denis et al. 2001; Lowe & Skitmore 1994). Thus, much of the information presently available on the costs of green projects, namely normative models of the cost of green features and descriptive studies of total project costs across larger populations of projects, does not provide the information that members of the constructor subsystem rely on when evaluating whether to change, particularly in high uncertainty situations. The third major category of existing knowledge, case-based explanations of cost premiums with regard to specific LEED credits, is a better match with the desire for information from peers, but to date, the set of such examples is quite limited, and information is organized by project feature rather than a translation of those features into the process-driven language of the constructor subsystem.

Conclusions: Overcoming Human Factors associated with the First Cost Barrier

In summary, the body of knowledge devoted to understanding and influencing the first cost of green projects is growing, but suffers from several weaknesses. With its focus on the owner and designer perspective, it fails to take into account some of the key factors involved in motivating the constructor subsystem to embrace sustainability as an innovation. In particular, the major attributes of innovations that correlate with increased adoption are all negative for sustainability when considered from the standpoint of the current constructor subsystem, although these challenges are not often appreciated by owners. Additionally, the types of information and evidence that are being assembled with the hope of motivating change across the industry do not match well with the types of evidence known to be convincing for later adopter categories, nor is it expressed in the language used by the constructor subsystem in planning and delivering capital projects. Together, these weaknesses represent an opportunity for research to better understand how the constructor subsystem establishes the cost of green projects, and what can be done to influence it.

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