Sustainable Innovation Diffusion in the Building Industry:

Barriers and Potential Interventions

Anthony J. Clarke

Undergraduate Honors Thesis

May 24th, 2012

The Collaboratory for Research on Global Projects at Stanford University is a multidisciplinary center that supports research, education and industry outreach to improve the sustainability of large infrastructure investment projects that involve participants from multiple institutional backgrounds. Its studies have examined public-private partnerships, infrastructure investment funds, stakeholder mapping and engagement strategies, comparative forms of project governance, and social, political, and institutional risk management. The Collaboratory, established in September 2002, also supports a global network of scholars and practitioners—based on five continents—with expertise in a broad range of academic disciplines and in the power, transportation, water, telecommunications and natural resource sectors.

Collaboratory for Research on Global Projects
Yang & Yamazaki Energy & Environment (Y2E2) Bldg
473 Via Ortega, Suite 242
Stanford, CA 94305-4020
http://crgp.stanford.edu

Acknowledgements

The research and findings would not be possible without the fifteen individuals who volunteered their time, experiences, and knowledge to produce the primary data for this honors thesis. Further acknowledgement extends to Dr. Raymond Levitt, who served as an academic advisor and mentor. Dr. Dana Sheffer deserves acknowledgement for her early guidance and the knowledge passed through her written works. Jeff Birdwell served as valuable industry resource. Dr. Mary Devitt deserves credit for helping organize my thoughts. This project would not have been possible without the funding support of Stanford's Collaboratory for Research on Global Projects and the Precourt Energy Efficiency Center. I would like to extend gratitude to my undergraduate and graduate advisors: Dr. Michael Lepech and Gary Griggs. Finally, I acknowledge Terry and JoAnn Clarke, my parents, who have supported me throughout my life.

Thesis Signature Page

Civil Engineering B.S.H. Written Submittal

Thesis Topic
Sustainable Innovation Diffusion in the Building Industry: Barriers and Potential Interventions

Anthony Clarke Bachelor of Science with Honors Candidate Master of Science Candidate Civil and Environmental Engineering Department	Date

Dr. Ray Levitt Thesis Advisor Kumagai Professor in the School of Engineering Civil and Environmental Engineering Department	Date

SUSTAINABLE INNOVATION DIFFUSION IN THE BUILDING INDUSTRY: BARRIERS AND POTENTIAL INTERVENTIONS[1]

Anthony J. Clarke[2]

[Submitted to Department of Civil & Environmental Engineering, Stanford University]

Abstract: Prior research on innovation diffusion emphasizing innovation is often complex and time-intensive. This thesis builds on three barriers to sustainable innovation diffusion identified in the research of Dana Sheffer and Raymond Levitt, namely: supply chain fragmentation, technological risk aversion, and stranded capital. Their research was based on analysis of large-N secondary data from LEED certification. This study validates, refines, and augments their work using primary interview sources. Fifteen interviews with industry experts located in Northern California, Southern California, and Chicago, and operating in the fields of architecture, engineering, construction management, real estate development, and real estate finance, provide primary data that ultimately validates and refines the research done by Sheffer & Levitt (2010). This paper concludes with potential mechanisms to overcome these barriers and offers ideas for future research on this subject.

KEYWORDS: Sustainable Innovation Diffusion, Supply Chain Fragmentation, Craft Administration, Knowledge Management, Broken Agency, Sustainability Champions

[1] This research was supported by the PEEC Grant; the Collaboratory for Research on Global Projects (CRGP); Raymond E. Levitt, Kumagai Professor in the School of Engineering in the Civil and Environmental Engineering Department at Stanford University; and Jeff Birdwell, Stanford Consulting Professor were advisors. The author gratefully acknowledges this support and advice. At the same time, the findings and conclusions in this paper are those of the author, and do not necessarily represent the views of these sponsors or advisors.

[2] Bachelor of Science Student, Dept. of Civil and Environmental Engineering, Stanford University. Email: aclarke3@stanford.edu

1 Introduction

The advent of sustainable innovation in the building industry improves on traditional methods of design, construction, finance, operation, and maintenance by enhancing a structure's lifecycle, economic, environmental, and social value. Malkin Properties, Zeta Communities, and Johnson Controls represent three companies in different parts of the construction industry supply chain that have derived profits from sustainable innovations. An overview of their successes serves as a backdrop for sustainable innovation diffusion in the entire building industry.

Malkin Properties spent an additional $20 million to complete a green retrofit as part of a $500 million renovation of the Empire State Building (Navarro, 2009). Anthony Malkin, president of Malkin Properties, expects a 38% annual energy savings and a three-year payback on the investment (Navarro, 2009). Regarding the project, he states "People associated green with expense and compromise. We're trying to prove: no compromise and payback" (Navarro, 2009). Mayor Bloomberg, whose administration emphasizes sustainability, praised Malkin Properties for showing "the rest of the city that existing buildings, no matter how tall they are, no matter how old they are, can take steps to significantly reduce their energy consumption" (Navarro, 2009). After its green repositioning of the Empire State Building, Malkin Properties moved to further capitalize the company in early 2012 by filing for a $1 billion real estate investment trust initial public offering, anchored by the Empire State Building (Agrawal & Mendonca, 2012).

Johnson Controls, a consultant on the Empire State Building Retrofit, often acts on behalf of building owners that wish to achieve utility savings. In some instances, Johnson Controls guarantees the operating cost to a property owner, applies energy efficiency measures to the building, and profits from the difference between actual vs. contracted operating costs. Johnson

Controls successfully retrofitted the Bank of America Plaza in Columbia, South Carolina. The 302,340 square foot, 17-story Class A+ office complex anchors an entire city block. Johnson Controls implemented a retrofit "resulting in an annual utility cost savings of over $43,000 per year with a 15% energy reduction and 40% water reduction" (Johnson Controls, 2010). Johnson Controls stands behind its sustainability motives. In fact "[t]hrough a building retrofit, the company's Corporate and Power Solutions headquarters in Glendale showcases the energy-efficient and sustainable building products and services [it can] provide to customers, with the [goal] of becoming the world's first LEED platinum-rated campus" (Johnson Controls, 2012).

Zeta Communities represents a third example of a company that benefits financially from integrating sustainable innovations into its business practices. Zeta Communities bought a mobile home manufacturer and retooled operations to produce net-zero energy urban infill homes. Zeta partnered with a local architect and structural engineer, Tipping Mar, to ensure the structural integrity of multistory urban infill housing in the earthquake-prone San Francisco Bay Area. Zeta Communities thrived in a down economy by creating partnerships throughout the supply chain. Now, the company is continuing to innovate by applying the same model to produce modular, energy-efficient school classrooms.

Malkin Properties, Zeta Communities, and Johnson Controls represent industry exceptions. Most companies in the building industry forgo sustainable innovations in their projects or fail to deliver sustainable projects (Choi Granade, et al., 2009).

At a top US university, a classroom, office, and laboratory facility exemplify unsuccessful sustainable innovation implementation. The 166,000 square foot building was designed with passive day lighting, heating, cooling, and night ventilation; automatically controlled operable windows, sunshades and fins; radiant floor heating; active chilled beam

cooling; heat recovery ventilators; photovoltaic cells; and recycled water. Despite advanced technologies, the building's systems required two years of operational refinement to perform at intended efficiency levels. Mechanically actuated night venting windows intended to open on cool summer nights instead opened on freezing winter nights, requiring make-up heating. Furthermore, a motion sensor activated in one classroom turned on the lights in an adjacent room—the sensors had been cross-wired.

What differentiates the aforementioned successful companies and the ones that built this university building? What drives successful innovation diffusion? What barriers retard successful diffusion? This paper uses the previous research of Sheffer & Levitt (2010) complemented by research from Ashcraft (2009, 2011); Gann et al (1998); Javernick (2008); Levitt et al (2011); Nam & Tatum (1997), Sheffer (2011); Sheffer & Levitt (2010, 2011); Stinchcombe (1959), Tatum (1989); Taylor (2005); and Taylor & Levitt (2004) to offer insight into these questions.

2 Point of Departure

Sheffer & Levitt (2010) identify both challenges to diffusion of innovations in construction and opportunities to overcome these obstacles. While Sheffer & Levitt used secondary LEED data to identify this framework, this thesis utilizes data from primary interview to validate, refine, elaborate—and possibly refute—the propositions developed in the Sheffer & Levitt research. Specifically, this document evaluates supply chain fragmentation, broken agency, technological risk aversion, and stranded capital as barriers to diffusion, and analyzes legislation and incentives, and corporate strategic actions as potential interventions. The following section provides an overview to Sheffer & Levitt's academic framework, which serves as a foundation for this research.

2.1 Supply Chain Fragmentation and Broken Agency

Sheffer & Levitt assert that the "detrimental effect supply chain fragmentation has on the diffusion of integral innovations is more pertinent today than ever, as more and more industries become fragmented" (2010). This thesis uses industry interviews to explore the impacts of supply chain fragmentation: horizontally (i.e. between mechanical, electrical, and plumbing subcontractors); longitudinally (i.e. from project to project); and vertically (i.e. between an architect, builder, and developer). Sheffer & Levitt suggest horizontal fragmentation of the supply-chain, combined with longitudinal fragmentation, creates most of the 'supply-chain learning disability' problems for integral innovations (2010, 2011). This paper evaluates how relational instability between firms in the supply chain retards sustainable innovation diffusion.

Sheffer & Levitt further assert that vertical fragmentation causes 'broken agency,' or misaligned incentives between stakeholders in the building process (2010). Specifically, "separate individuals, different departments within an organization, or different companies incur the risks and benefits associated with each phase of a building project's life cycle, so no individual or firm on the project has a truly multidisciplinary, life cycle perspective" (Sheffer and Levitt 2010). Ultimately, varied stakeholder interests impede innovation diffusion, while aligning interests, as in integrated project delivery, facilitates shared motivation and the opportunity for diffusion (Ashcraft, 2009 & 2011). This thesis analyzes how innovations lead to conflicting motivations across supply chains, resulting in disparate benefits and risks for the different stakeholders.

2.2 Technological Risk Aversion

Sheffer & Levitt further suggest that the "technological risk aversion that is present in the building industry has to do with the combination of high costs and long time horizons" (2010).

Unlike other industries that offer product recalls or have short replacement periods, a properly designed building will last decades, even centuries. This document describes how the long-lived implications of building decisions decrease the stakeholder's willingness to experiment with technological innovations.

2.3 Stranded Capital

Sheffer & Levitt state that "[a]n exceptionally high level of demand fluctuation—several times greater than the overall business cycle—plagues the building industry. This is an additional constraint to diffusing innovative building technologies, because investments become stranded capital when demand turns down, as it did so viciously in 2009" (2010). Now, over four years removed from the onset of the great recession, economic conditions have yet to recover completely. The market cyclicality and demand fluctuation make large investments in designing and delivering innovations in more integrated companies risky. Integrated companies run the risk of being brought down by the next demand gap, as seen historically with George Romney's 'Operation Breakthrough' initiative in the 1960s. This thesis assesses how economic conditions and cyclicality directly affect the rate of innovation diffusion.

3 Research Strategy and Methods

The study focuses on fifteen face-to-face or telephone interviews, conducted between July 2011, and February 2012. Participants responded anonymously to twenty open-ended questions (Appendix D). Interview participants represent three geographic areas – Northern California, Southern California, and Chicago – and a number of levels across the supply chain – architecture, engineering, construction management, development, investment, and finance. The final interview distribution is displayed below:

FINAL INTERVIEW DISTRIBUTION

	Architecture/ Engineers	Construction/ Development	Investment/ Finance
Northern Cal	x	xxx	xx
Southern Cal	x	x	xxx
Chicago	x	x	xx

* 15 Interviews Total

Interview questions were divided into five categories:

1. General Industry Background,
2. Cases with Sustainable Innovations Considerations,
3. Cases without Sustainable Innovations Consideration,
4. Industry Fragmentation & Integration, and
5. Conclusions.

The questions were open ended to catalyze conversations rather than providing a rigid framework to gather specific answers. As a result, each interview covered unique experiences, projects, and stories.

Altogether, fourteen of the fifteen interviews were recorded and twelve were transcribed. Throughout the research process, one interviewee opted not to be recorded and two recordings were of poor quality due to the nature of the interview. The program NVivo allowed transcribed interviews to be coded based on research themes. Filtered coded data allowed nuanced findings to emerge. Key research information was first generated from NVivo data and complemented by notes from the other three interviewees (although not transcribed, detailed notes allowed interview findings from all three to contribute to this research paper). A number of mitigation strategies, such as including diverse perspectives and asking open-ended questions, reduced the selection bias and interview bias associated with interview-based research and the small sample size (Appendix B).

4 Barriers to Sustainable Innovation Diffusion

As mentioned previously, the body of the thesis applies analysis of primary interview data to validate, refine, elaborate and possibly refute the propositions developed in the Sheffer & Levitt (2010) research. This thesis begins with challenges to diffusion and later continues with proposed solutions. This section addresses Sheffer & Levitt's frameworks of innovation barriers caused by *supply chain fragmentation*[1]*, broken agency, technological risk aversion,* and *stranded capital*.

4.1 Supply Chain Fragmentation

This paper evaluates how relational instability causes horizontal and longitudinal fragmentation within the supply chain, which flattens and over time impedes sustainable innovation diffusion. The analysis then addresses vertical fragmentation, known as broken agency, and how innovations across supply chain levels result in conflicting motivations for stakeholders. Please note throughout this thesis, propositions introduce the author's arguments.

4.1.1 Horizontal Fragmentation – Drawback of Craft Administration

Relational instability within the same supply chain level hinders sustainable innovation diffusion. The interviewees suggest many firms fear innovation for reasons discussed later in the paper. However, even the most innovative firms lack the established lines of communication with other firms in their supply chain level that they require for greater scale innovation diffusion.

---

[1] Supply chain fragmentation was identified by John Taylor (2005) as a barrier to the diffusion of systemic innovations —innovations that require multiple supply chains firms to adapt their products or processes simultaneously. The impact of supply chain fragmentation in retarding systemic innovations was validated in an analysis of secondary LEED data sources by Sheffer (2011).

Proposition 4.1.1: Due to the limited extent of horizontal integration, even firms that specialize in implementing sustainable innovations do not work in intimate and repetitive contact with firms at the same supply chain level. Thus, effective strategies and knowledge are not passed to other companies at the same level of the supply chain.

Interviewees indicate that innovative firms are isolated from traditional firms, which blocks knowledge transfer. These findings support the work of Stinchcombe, who argues the uniqueness of each construction project and the requirement that skilled workers adjust to a new project's design, size, and location lead to craft administration that is more typical in the construction industry than bureaucratic administration (1959). While craft administration seems like a sensible organizational design for construction firms, it simultaneously isolates firms from their peers at the same supply chain level. Researchers like Ashcraft (2011) propose Integrated Project Delivery (IPD) as an alternative project organization, employing "virtual horizontal integration" within the IPD framework to take advantage of the firms' craft administration. He argues, "IPD seeks to reap the benefits of specialization while molding the disparate parties into a virtual organization that is aligned to the project goals. It does not negate existing roles such as designer of record or builder, but integrates them into the larger whole" (2011). An integrated project delivery approach allows for knowledge transfer within a supply chain, without resorting to bureaucratic administration. As an aggregate, these interviewees validate Sheffer & Levitt's argument that relationship instability within the same supply chain level pervades the industry, but refine their argument by noting IPD principles allow for the stability necessary for knowledge exchange.

4.1.2 Longitudinal Fragmentation – Knowledge Management

The previous section discussed how relational instability within supply chain levels impedes sustainable innovation diffusion. This section focuses on relational instability from project to project. Again, the lack of stability blocks the flow of knowledge necessary to cause innovation over time.

> *Proposition 4.1.2A: Inefficient or nonexistent longitudinal integration blocks knowledge and experience flow from project to project. Thus, firms lose valuable lessons that could translate into better implementation of sustainable innovations in future projects.*

Rather than documenting past sustainable projects, many firms rely on human capital to maintain their knowledge in sustainable building design. One firm describes their practices:

> *Investor: I think if you were to talk to our [Company Chief Operating Officer] ; [Construction Manager]; [Company Managing Director]; or myself [Company President], collectively we've all done a number of different projects and we know what projects are more successful and we know what projects are less successful. […] We don't have anything formal.*

An architecture firm also notes its reliance on human capital:

> *Architect: There's this notion of human capital, in a company this size, you don't necessarily need a drawer full of documents.*

Small companies appear to prefer human capital rather than a physical record of projects. Unfortunately, accessibility to human capital diminishes as these firms grow, people move between firms, and companies abandon formal knowledge management strategies altogether:

> *General Contractor: I'm not aware of an ongoing database that records each project.*

A behavior possibly even more troubling is only reporting projects that went well. This practice presents a skewed perspective of best practices and company capabilities.

Proposition 4.1.2B: A number of firms only report their successes in sustainable design, both internally and externally.

Only reflecting on successes impairs decision-making and makes it impossible for a firm to learn from its mistakes, a necessity for future innovation (Petroski,1992). An investor states:

Investor: We only like to document our successes. There's probably not a lot of written documentation, but it's a lot of our collective experience.

Relying on human capital to pass along information limits the extent of information exchange within a company and between companies. Employee turnover further compounds this problem. The companies that supplied this information were generally smaller firms with employees who worked at the firm for the majority of their career. Relying solely on human capital alone to learn from and transfer innovations is clearly insufficient and needs to be supported by a recordable methodology. Passage of information in this manner is not only a problem from project to project, but also from "vertical fragmentation" between one phase of the project and the next (Ibrahim and Nissen, 2005). A developer notes how vertical fragmentation is a barrier within projects:

Developer: If you are in the middle of a project and suddenly decide you want to go for LEED it's very difficult to go back and figure out how to get the points through things, which are already done.

Recording sustainable innovations tends to be a barrier to innovation. This is also the case in post-project evaluation:

Proposition 4.1.2C: Post-occupancy evaluations are limited as cost saving measures, which reduces feedback on whether or how a design achieves sustainable goals and also reduces some firm's motivation to assign their capable personnel towards attaining sustainable goals.

It is difficult to get feedback even for project level actors because relationships are rarely sustained beyond the construction period.

Architect: Very sophisticated systems go in and there are supposed to be all these wonderful things and on paper it looks great, but you must test it out.

Owners do not want to keep key staff on during the operations phase of the project:

Architect: [Owners] don't really want [us] to be billing it.

Relationships are not sustained from one project to the next and records are often not kept, making it difficult to evaluate, and adapt or re-implement, successful innovations from project to project. Innovation diffusion cannot occur without constantly improving the end product. One general contractor shared how his company places its least experienced staff on processing LEED documentation for the project,

General Contractor: Kids fresh out of school are tasked with dealing with the LEED issues.

The general contractor admits to an unsettling truth. Since his or her company does not financially benefit from achieving LEED certification of the building, the company places little emphasis on ensuring the building's lifecycle efficiency.

Knowledge management proves to be a prevalent issue throughout the Architecture, Engineering, and Construction (AEC) industry. Javernick-Will describes how Fluor uses "a web based knowledge management platform 'Knowledge Online'" (2008) to create knowledge

communities within the company, allow for searches for information, and offer online forums. 'Knowledge Online' "combines social networking and document management to meet the business objectives of the firm" (2008). No doubt this global technology platform contributes to Fluor's sustained success and represents a dramatic difference from the practices of the companies interviewed who use purely 'human capital' or only 'report successes'. Based on this paper's research, knowledge management represents a significant hurdle for longitudinal integration and project-to-project learning.

4.1.3 Vertical Fragmentation – Broken Agency

Thus far, the thesis has evaluated relational instability within supply chain levels and over time. This section focuses on vertical fragmentation or the misaligned incentives between stakeholders across the supply chain, known as broken agency. Sustainable innovation diffusion suffers from supply chain fragmentation across 'swim lanes' in the building industry, hindering the exchange of knowledge and experience (Sheffer & Levitt, 2010). The interviewees indicate that vertical fragmentation separates investments from returns on those investments, and thus spawns knowledge discrepancy and a resulting belief in the financial infeasibility of sustainable innovations. Beginning with knowledge discrepancy:

> *Proposition 4.1.3A: Supply chain levels closer to the onsite assembly phase tend to have more experience and therefore more knowledge of sustainable innovation. Conversely, supply chain levels further removed from the onsite work tend to have less experience and therefore less knowledge of sustainable innovation. This relationship retards innovation possibilities.*

It is often the case that actors who do not have the final decision making power have the knowledge required to successfully implement sustainable technology and actors who have the decision making power lack the knowledge and experience to make them.

> *Developer: We were pushing them to use insulated glass because of the performance. We did a life cycle analysis to prove that over the course of the building life and over the course of maybe four or five years payback, it would pay dividends on the energy cost [and reduce the] mechanical system sizing because the overall load of the building would be greatly reduced.*

Architects, engineers, general contractors, and developers all find themselves attempting to convince owners or investors with misaligned incentives to include sustainable technologies in their projects. Organizations who value sustainability often are conflicted about whether to accept projects where sustainability is not prioritized. Taking the product would add company revenue, allowing the business to pursue green motives in the future but possibly compromising the company's core values in the short term. An architect discusses how his company proceeds when they see potential for successful implementation but are unsure as to whether the owner wants to see these changes delivered:

> *Architect: We've said let's go and improve it and make it better, rather than turning it down.*

Rather than rejecting a job based on company values, the architect decided to shape the project from within. The term 'broken agency' (Sheffer & Levitt) describes the conflict that often exists between stakeholders. General contractors also experience broken agency with an owner/investor:

General contractor: I have worked on projects where clients have said 'I understand what you are saying, I understand the user of this building could [realize] 5 or 10 percent [savings] in energy cost from here on out, but that's not my problem. My problem is meeting a pro-forma, and my pro-forma needs to minimize initial cost and that's how I make the greatest fee and walk away from this, get the most money in my pocket.' If you are totally dollar driven then that's what it is you are going to do; you are going to make that decision, and people do that.

In both cases, owners and the actor completing the project stand to gain differently from the project's completion. This finding parallels the next proposition, which suggests supply chain levels closer to the project have a better feel for diffusible innovations:

Proposition 4.1.3B: Supply chain levels closer to the project level tend to be more adept at achieving voluntary or mandatory certifications like LEED and Energy Star than those further removed from project level tasks.

As a result, firms closer to the project level retain more knowledge of and experience with sustainability than those removed from project level operations. Lack of vertical integration perpetuates a long-existing industry belief that sustainable innovations are not financially feasible. A number of these perceptions supporting this claim prevent the building industry from innovating and result in a biased belief in the financial unfeasibility of sustainable innovations:

Proposition 4.1.3C: Initial profitability and immediate return on investment remain a priority over sustainable design, construction, development, and investment. This trend is more prevalent higher in the supply chain.

The concept of "green" remains laughable in certain sectors of the building industry:

Developer: "I was asked if we wanted the building to be green – I said 'why not red or orange? The only green I care about it is the green in my pocket".

A financier shares this sentiment:

Financier: You're still just looking to make a dollar.

The developer and financier in the cases above believe achieving both "green" objectives—profit and environmental—is impossible. Others point to the perceived tradeoff between a desired space and a space that includes sustainable innovations:

Investor: Small companies or growing companies are really going to work at the bottom line and look at their cost and want to minimize that. They get the nicest looking space they can to achieve. […] Companies are looking at maximizing their TI (tenant improvement) dollars.

These investors identify aesthetic quality and size of the space, rather than its energy efficiency, as motivating their tenants. The general sentiment in the building industry remains that profitability and a sustainable building do not coexist:

Proposition 4.1.3D: A sustainable building and a profitable building are perceived to be incongruent. This perception is more acute higher in the supply chain.

Decision-makers frequently fear the initial first costs associated with sustainable building technologies:

Architect: If you just can't afford the upfront cost, then it's something that it gets tabled, and that has to be generated from the client side.

A general contractor adds:

General Contractor: If it's going to cost them more, it's going to be a challenge.

A financier continues on the subject:

> *Financier: When it comes down to it, it's dollars and cents that they are going to make the decision on.*

These quotes demonstrate the bottom line drives decision-making and, for many firms in the AEC industry, the return on investment for sustainable innovations is difficult to quantify. This level of uncertainty regarding the payback and valuation of the asset limit innovation. The interviewees point at the difficulty in truly assessing the value of sustainable innovations:

> *Broker: Obviously, it's a benefit. Then again, it's just tough to quantify. I don't know if people actually pay more money for LEED.*

Furthermore, property owners and investors do not stand to gain when tenants are paying their pro rata share of the energy bill under "triple net leases". This form of broken agency is a challenge that pervades the real estate investment community. Prospective tenants often do not pay attention to the utility prices when selecting between rental opportunities. Instead, the monthly rent is the key financial metric. In a triple net lease, the tenant pays an energy bill based on the ratio of square footage rented compared to the overall rentable square footage in the building. Therefore, energy savings in the building have no impact on profit and loss for the landlord. If a landlord opts to shift to a full service gross, where the tenant pays one agreed monthly rate and the landlord incurs the operational costs, then their rents appear above market and are not competitive. An engineer speaks to the difficulty of actually realizing financial profit from energy-efficient spaces:

> *Engineer: You basically have to be separately metered. You know a lot of the sockets, it's multi-tenant and their operating costs are just based on their [plug] load factor and just pass through so we don't really see that.*

The building industry is made up of unsophisticated users of sustainable innovations.

Proposition 4.1.3F: Lack of experience or familiarity with forecasting financial returns on sustainable building innovations deters diffusion.

Essentially, actors across the building industry do not know how to value sustainable buildings and therefore fear implementing a technology for which they cannot predict returns on investment.

Investor: When we were buying a building I wouldn't look at it and say okay, it's worth $40 million, but because of LEED it's $44 million.

Valuation uncertainty pervades the industry:

Investor: There are some funds where we target green-type tenants, but I don't know if it really moves the needle on valuations. […] I don't think we look at a building and, if it was LEED, add extra value to it for being LEED.

This set of quotes indicates that firms in the markets interviewed for this study fail to perceive the correlation between financial returns and sustainable innovations. Despite this uncertainty, many investors do agree it accelerates the leasing process, benefiting the bottom line:

Investor: Funds are very focused on returns and [won't] spend the money for the sake of being green, but if there's a way to show it's going to help with our leasing efforts then they want to be doing it.

One developer acknowledges leasing speed associated with sustainable innovations:

Investor: LEED certification is probably going to cost us anywhere from 15 to 20 bucks a square foot for the size of their lease which is not insignificant, but it's going to give that building a marketing advantage from a leasing standpoint.

An investor confirms sustainability reduces building vacancy:

Investor: It is a very difficult thing to quantify. I usually tell people the benefit is in reducing the downtime it takes to lease up a project because it is more appealing to the tenants.

A robust methodology for valuing such innovations in a building is essential for faster and broader industry diffusion. Besides valuation complexities, the industry standard of short-term relationships with buildings inhibits diffusion:

Proposition 4.1.3G: Short building, development, or investment time horizons with buildings reduce payback periods and therefore reduce the financial feasibility of sustainable innovations.

Short time horizons of up to a few years cause actors to lack incentive to a take a life cycle perspective.

Investor: Our investment focus historically is changing a little bit now, but it's always been driven by a short holding period.

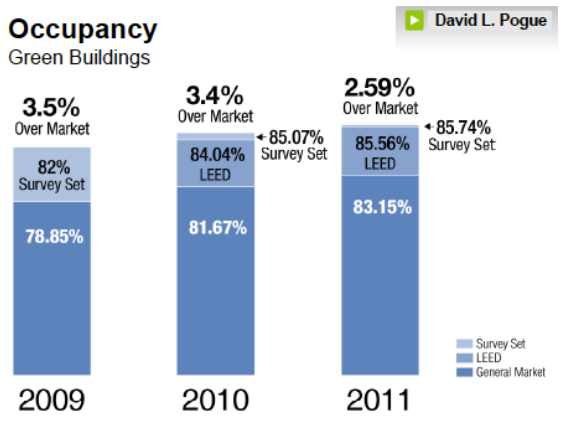
High-yield investor interests generally do not align with sustainability:

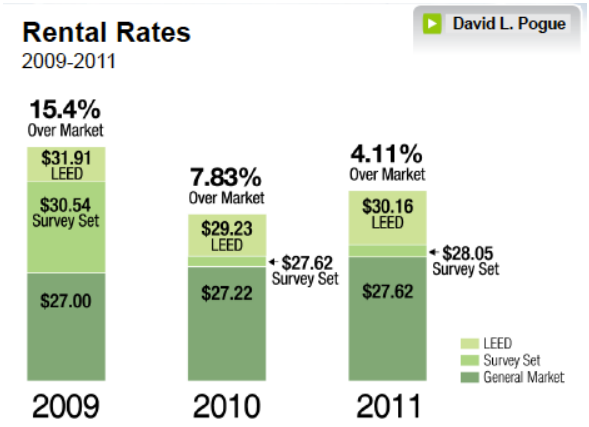
Investor: Our investment focus is to go into a property, reposition it whether that's through the leasing side, through the construction renovations side and then, sell the asset. We're not typically a 20-year holder; we're more of a 3 to 5 year holder.

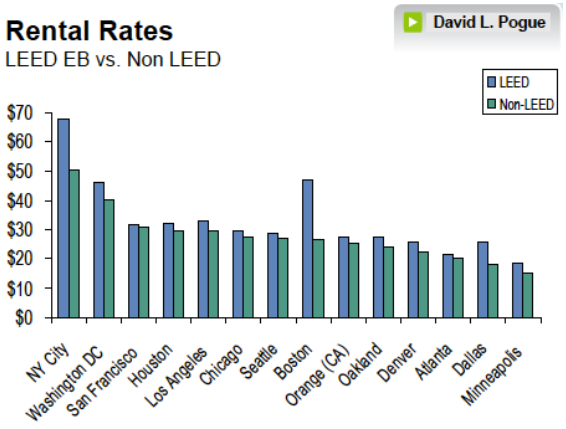
The prevailing investor sentiment is short investment periods do not allow for profitable sustainable innovations. However, a few actors within the financial industry argue sustainable innovations can shorten time horizons and be advantageous within current company structures. In fact CBRE, global leader in real estate services, recently completed a study indicating green buildings "have a 3% higher occupancy, have higher rents by 2-5%, have higher effective rents

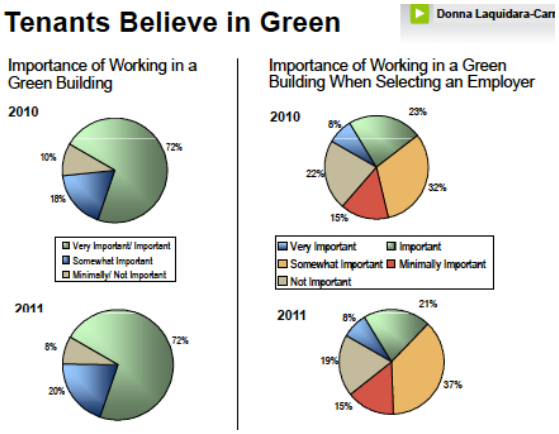
by 6-7%, and have higher selling prices by 11-13%" (Kampschroer et al, 2011). The study indicates tenants often see working in a green building for a green employer as a priority.

In clockwise rotation starting in the upper left, the study illustrates annual occupancy impacts, rental rate increases by year, tenant belief in green buildings, and rental rates by city.









While most interviewees argue the value of green buildings is unquantifiable, CBRE's study measures the financial impact of sustainable innovations. For example, LEED buildings were sold for an average of $11.3 million dollars higher than non-LEED buildings. Studies like this validate the bottom-line impact of green buildings and begin to align incentives across the supply chain.

4.2 Technological Risk Aversion

Supply chain fragmentation and broken agency impede diffusion, as established in the previous sections. However, even when the supply chain is engaged and incentives are aligned, technological risk aversion delays diffusion. Lack of knowledge and experience was previously mentioned as an example of improper integration of skills across the supply chain. Yet, unique technologies or applications slow implementation, regardless of previous experience. Besides lack of knowledge or experience, the associated hard and soft up-front capital costs contribute to technological risk aversion.

> *Proposition 4.2: Across nearly all supply chain levels, perception that sustainable innovations require additional hard and soft up-front capital retards diffusion.*

Hard costs, such as more expensive sustainable materials, require additional capital thus lowering profitability. One developer acknowledges how his company tries to minimize up front costs:

> *Developer: We try not to spend a whole lot of capital upfront putting in green technologies without knowing how important that is going to be for our tenant.*

The same developer goes on to say:

> *Developer: We are trying to lease space to [a large tenant] and they had huge requirements on LEED. The building had to be LEED Platinum, so we have to figure out, okay, how much is it going to cost for us to get the Platinum? If it doesn't make economic sense to do all this work, we will get the standard tenants instead.*

A general contractor adds:

General Contractor: If you are talking to a Fortune 100 company, you know, maybe they'll go the extra mile for something like that because of the marketing concept of it.

Incorporating sustainable innovations becomes possible through communication between project stakeholders. An architect describes this iterative process:

Architect: There's constant dialog because they actually take our designers back to their manufacturing facilities and we brainstorm with their designers and try to forward think where the work place is going and how we can better serve the end user. It's not one size fits all anymore.

In this case, the architect partners with the manufacturers to limit technological risk aversion. This manufacturer warrants product performance, allowing the architect to specify its product without incurring liability risk for the initial hard cost investment in creating a desirable end product, in case of a failure of the innovation to achieve its claimed performance advantages.

Soft costs, such as documentation associated with LEED Certification, result in no building improvements but affect project profitability. Individuals across the supply chain agree the cost of completing LEED documentation is a deterrent to innovation. These soft costs cause technological risk aversion by increasing the cost of innovation. An established developer expresses his disgust with soft costs:

Developer: "$300,000 in fees to get a subsidy?"

Soft costs also come in the form of lost time:

General Contractor: That has helped guide through the program because …there is a lot of documentation that goes into getting these LEED certifications.

The same general contractor continues:

> *General Contractor: It's almost like you have to have another advisor or another person on the job to report all these things and to turn it in to the appropriate people.*

An investor mentions that it is simply not worth their time to process LEED certification:

> *Investor: Even though two of us here in the office are LEED certified, I don't need to spend my time on underwriting opportunities and trying to buy buildings. It's just more efficient to pay someone who's more of an expert at LEED documentation to handle that.*

When determining whether to incorporate a new sustainable technology, the AEC industry considers both the hard and soft costs associated with the product. Even if the product's value outweighs these costs, the quick advancement of technology also represents a significant risk.

> *Engineer: The expiration date on the technology that they are installing and the building is short and they have to be on line very quickly to take advantage of potential opportunity for the person developing the project.*

Owners and developers run the risk of technological innovations becoming obsolete by the time of installation. Sheffer & Levitt (2010) identify technological risk aversion as a barrier to innovation diffusion. These interviews validate and elaborate their findings, noting that technological risk aversion derives from hard and soft costs, including time delays, and the rate of technological advancement.

4.3 Stranded Capital

Thus far, this thesis has covered supply chain fragmentation and technological risk aversion. This section focuses on stranded capital, describing how rapid demand fluctuation leads to

stranded and distressed investments. This demand fluctuation makes mobilization and integration of companies cumbersome because market conditions change rapidly during a company's evolution. Sheffer suggests, "vertical integration is positively associated with the rate of diffusion;" however, demand fluctuation increases the risk of such integration. As the economy recovers from the great recession, economic resurgence in various regions correlates with a positive attitude towards sustainable innovation. The interviews focused on three specific geographic regions—Northern California, Southern California, and Chicago. Their vibrant market conditions cause a positive perception of sustainable innovation.

> *Proposition 4.3A: Mentality towards sustainability correlates with economic condition and real estate price resiliency of the geographic region.*

The Bay Area has witnessed the most significant real estate recovery of the three geographic areas studied, partly due to the thriving technology sector located in Silicon Valley. Economic growth serves as a catalyst for sustainability, as the fear of stranded capital is less significant in the Bay Area. Local investors in the Bay Area agree the rate of sustainable innovation diffusion is increasing:

> *Investor: I have been in Silicon Valley for about four years now and I have seen [sustainable innovation] steadily increase here. […] My hunch is that we are on the kind of forefront of this— that the Bay Area is kind of leading the nation in these efforts and I have definitely see an uptick, and obviously in LEED projects and in tenants requiring green build outs.*

Another investor agrees:

> *Investor: I think it already has spread, I think we saw it with (a property the company owns in San Francisco), I don't want to say late, but we didn't see it*

earlier just because of the market, it's been more difficult to lease that building. And so when the right tenant came, and they also said, "We want a LEED building" we said, "Of course".

According to a financier in Chicago, the Bay Area is considered "the leader in sustainability", which correlates with a strong real estate recovery. The economic climate in the Bay Area is a driver of its leadership in the sector because the risk of stranded capital is relatively small. Southern California, which has experienced a moderate recovery in its real estate market, has seen growth in sustainable innovation, but not to the same degree as the Bay Area. Los Angeles investors recognize this, but some assert interest in sustainable innovation is growing:

Investor: But tenants in LA are beginning to ask about it too.

The same investor continues:

Investor: To the extent that you can improve operating margins, I think any investor would support spending money on improvement projects. But I haven't heard of any investors requesting that we as a principal search out sustainable buildings.

As Southern California is in the middle of the three regions in terms of recovery, it is also in the middle in terms of sustainable innovation diffusion. Stranded capital remains a significant fear in the Chicago area. Current regional economic conditions have forced emphasis on first cost metrics over life cycle costs. The economic climate has slowed new construction, thereby slowing the adoption of sustainable components. This Chicagoan architect explains the current condition:

Architect: New construction is something we haven't seen a lot of over the last couple of years either because of the way that the economy has been.

A developer mirrors this economic sentiment:

> *Developer: We're also dealing with cash-strapped organizations facing huge funding cuts.*

As there is less certainty overall in the area, the risk of the stranded capital increases. For example, lenders are less willing to value sustainable innovations in buildings:

> *Investor: Now with our lenders, it's something nice to check a box, so to speak, that it's a green building. But it's not a deal killer if it's not. […] We do get asked that more on a new building environmentally what's going to be involved, is it a green building. […] I haven't necessarily had anybody turn down a deal, if it wasn't going to, you know, have all the bells and whistles of being a green building.*

The starkly different approaches from actors across these three regions demonstrate that stranded capital is a real risk and a barrier to diffusion, particularly when economic resources are unstable. Sheffer & Levitt suggest "stable alliances or joint ventures could replace vertical integration as the best strategy to accumulate learning while reducing the risks associated with demand fluctuation" (2010). Further research into the relationship between economic conditions and diffusion is required to examine whether stable alliances or joint ventures are successful in areas, like Chicago, where stranded capital is a significant project risk.

5 Potential Interventions

The previous sections built predominantly on the prior research of Sheffer & Levitt, evaluating the barriers to sustainable innovation diffusion they previously identified. Now, this thesis applies primary interview data to validate, refine, elaborate and possibly refute their proposed solutions to these challenges. These solutions include legislation, incentive plans, and corporate

strategic actions. The body of this section concludes by proposing an additional intervention related to sustainability champions.

5.1 Legislations & Incentives

Sheffer & Levitt assert "intervention by government—through regulations, codes, incentives, or other policies—is generally justified in circumstances in which market failures result in outcomes that are less than optimal for society" (2010). They note "regulation can be quite effective; in fact, codes are a standard solution to deal with the problem of broken agency" (2010). Research verifies government regulations and programs catalyze sustainable innovation diffusion:

> *Proposition 5.1A: Government regulation and programs drive sustainable innovations.*

Local, state, and federal government tax regulations and credits enable leaders throughout the supply chain to integrate sustainable building features. The California Title 24 building energy regulations and even more progressive building codes in a number of California cities, like Santa Monica and San Francisco are driving sustainable innovations. This Bay Area architect points how an ordinance inspires sustainability. The architect shares:

> *Architect: It is a San Francisco ordinance mandating certain levels of performance for your building. [...] It is a requirement just like the California Building Code. […] It is a guideline that you have to meet if you are building in San Francisco.*

Other interview sources agree regulation accelerates diffusion and refers to his or her experience in West Los Angeles:

Investor: Building codes have been pushed for a number of reasons to align very closely with standards required for LEED certification.

The emerging alignment between LEED and building energy codes allows for standardization of products and mitigates risk for stranded capital. In fact, LEED Silver is becoming nearly a standard building practice in parts of Southern California:

Engineer: The City of Santa Monica is very environmentally conscious, as is the City of West Hollywood where public buildings have to be silver.

A developer mentions how Santa Monica goes even further as the fire marshals and building regulators actually accelerate the building process for LEED buildings:

Developer: You get an expedited plan check. […] You go to the head of the class.

Beyond these benefits, government regulations and standards create a competitive edge for companies that incorporate sustainable innovation diffusions in their building practices:

Proposition 5.1B: Government backed or voluntary programs like Energy Star and LEED provide a structure for sustainable implementation across the supply chain for industry members who able to implement them.

Firms knowledgeable of the building code, LEED, and Energy Star have a competitive advantage. Now that sustainability is being regulated in particular areas, firms that refuse to innovate will be left behind. Investors will be forced to innovate:

Investor: Aren't there some sort of tax credits they can get or things like that?

Companies who understand sustainable regulations have an advantage compared to their competition. Public utility rebates offer an incentive for developers and investors to improve existing structures, and allow architects and engineers to design new buildings that are focused on minimal use of materials and energy. While a number of cities are leaders in regulating

sustainability innovation, many industry professionals desire more innovation and believe cities are more interested in publicity than innovation. Sheffer & Levitt introduced legislation and incentives as a potential intervention and this research validates this conclusion. However more work must be done to align legislation and incentives with continued sustainable innovation.

5.2 Corporate Strategic Actions

Gann et al (1998) argue legislation and incentives are not sufficient for sustainable innovation diffusion. Corporate strategic actions are another potential intervention, as large companies demand sustainable initiatives, thus driving diffusion. It is important to remember that the owner or investor retains final decision-making authority:

> *Architect: The client has to decide whether they want to go for certification. So ultimately it's the client's decision.*

As such, corporate strategic action can alter the green innovation space:

> *Proposition 5.2A: Corporate entities have the potential to break through innovation barriers because of their public exposures, their influence, and their balance sheet.*

Large general contractors and universities are examples of corporate entities that believe it is in their interest to be perceived as sustainable. Corporations are encouraged to be sustainable because they benefit in terms of reputation:

> *Proposition 5.2B: Tenants of larger organizations and companies tend to desire green spaces more than those from smaller organizations since larger organizations can afford additional capital requirements and will pay a premium for their corporate reputation.*

This phenomenon was uniformly accepted by all interviewees:

Investor: A small law firm isn't going to care so much, […] but if you are talking about big tenants that is where we see LEED demand.

Another investor echoes the same sentiment:

Investor: British Aerospace just adopted a green initiative and determined their new space is going to be built with green technologies. […]That's just symbolic of a trend that you see with a lot of larger companies.

A developer supports this argument as well:

Developer: Companies that are larger, the Fortune 500 guys, are the ones who have the money to push the green initiative. They are also the ones that have the bigger impact on the community if they are not green and they have a PR issue. A big company like Hewlett Packard needs to be able to tell the world that they are doing everything they can to reduce their carbon footprint because they are such a massive force and so it's important for them to be able to present themselves in the media as such.

We even see that some investment funds undergo sustainability drives:

Investor: A lot of large, pension funds that have a component of their investment that has to be done in energy efficiency, green-type of buildings.

Whether it is a general contractor, university, Fortune 500 Company or investor, corporations shape sustainable innovations.

5.3 Sustainability Champions

Sheffer & Levitt originally pitched legislation, and incentives, and corporate strategic actions as opportunities to accelerate innovation diffusion. In this final subsection, this thesis adds sustainability champions to the working knowledge of this field. Champions for sustainability

drive innovation diffusions. This proposition builds on the research of Nam & Tatum who argue, "…effective leaders are essential for technological innovation – in particular in construction" (1997). This also holds true for the subset of sustainability innovations in the construction industry:

> *Proposition 5.3: Passion remains a primary driver of sustainable innovation diffusion. Leaders in each supply chain level are pushing sustainable innovation and their successes promote diffusion.*

Throughout the interviews, one factor of sustainable innovation diffusion stood out. This factor exists, but does not trend by supply chain level, geographic location, or size of firm. Particular companies and individuals are passionate about sustainable innovations in the building industry. They are not necessarily motivated by profit, publicity, or outside influence. Rather, these sustainability champions enjoy making a difference, being part of something larger than themselves, or simply adopting a pro-sustainability mindset:

> *Architect: It wasn't called sustainability. It was just called good building practice when we would try to get materials that were renewable and also performed from an industry standpoint, and also keep the building innovative.*

In addition to following sustainability best practices, these individuals display a general excitement towards sustainability:

> *Investor: I'm excited to take (a property) to LEED-certified.*

Sustainability champions identify sustainable innovation diffusion as a process or movement over time. It is part of their core values as business people:

General Contractor: I would say that we always look towards sustainability and sustainable products. […] I think it is in our core from concept through the initial implementation of the project as far as construction.

An architect mentions a similar thought:

Architect: It's basically innate and kind of integral in our design process. It's just second nature.

A few sustainability champions internalize sustainability as a personal lifestyle that comes through in their building methods as well:

General Contractor: I happen to be a fairly sustainably-minded sort of individual. […] I've recycled cans and bottles when I was in high school. And you know, it sounds like a kind of silly thing, but I set up a recycling program in the fraternity house while going to school. They thought I was crazy.

Another sustainability champion has made a career out of this passion:

Architect: My career has been probably spent more of the time working in the sustainable realm than not.

Other sustainability champions are companies rather than individuals:

Engineer: Disney was always environmentally conscious even when I was there although LEED didn't exist yet.

Finally, sustainable champions see unsustainable measures and practices as nonsensical:

Architect: That doesn't make sense to me. That's not a sustainable thing.

6 Conclusions

The findings from this thesis provide additional validation for the Sheffer & Levitt (2010) framework to explain sustainable innovation challenges and opportunities. Throughout the

interview process and ensuing analysis, relational instability stands out as the most significant impediment to sustainable innovation diffusion. Supply chain fragmentation, stranded capital, and technological risk aversion all flow from relational instability int eh supply chain, exacerbated by demand fluctuation for the product. This paper refines and extends the research of Sheffer & Levitt by:

- connecting horizontal fragmentation to the prevalence of craft administration in the AEC industry;
- associating longitudinal fragmentation with a lack of knowledge management; by identifying that the misaligned interests that cause broken agency could be aligned through studies like the one introduced by CBRE;
- refining technological risk aversion as influenced by hard costs, soft costs and the rate of technological advancement;
- connecting stranded capital to growth rates and demand volatility in different geographical markets; and
- extending Nam and Tatum's (1989) concept of building industry champions by indentifying sustainability champions as agents of change for enhanced building energy efficiency.

This research adds validity to Sheffer & Levitt's research (2010) by providing additional support for their findings, which were based on analysis of LEED point data. Some key limitations of the research include the small sample size of interviewees, lack of generality outside the focus of the three geographic regions identified, and potential interviewee selection bias. While the range of studies hopefully allows findings to be applicable within the United States, future research would

be required to assess the validity of these findings abroad and particularly in developing markets such as Brazil and India.

7 Future Research

Future research on sustainable innovation could build on and extend this thesis by addressing areas of Sheffer & Levitt's research this paper did not address in detail. Additional research could focus on describing the effects of modular versus integral innovations with a specific focus on sustainable building features. Further research could also look at consumer education as a potential intervention. Alternatively, additional research could help generalize these results throughout the United States or abroad. It would be particularly interesting to compare results from the developing world to those found in this thesis.

8 References

Agrawal, T. & Mendonca, J. (2012, February 14). New York real estate market looking up. *The Gazette*. Retrieved February, 2012, from http://www.montrealgazette.com/business/York+real+estate+market+looking/6148090/story.html.

Ashcraft, H. (2009). IPD Frameworks. *Hanson Bridgett*. Retrieved February, 2012, from www.hansonbridgett.com/Publications/pdf/~/media/Files/Publications/IPD_Framework.ashx.

Ashcraft, H. (2011). IPD Teams. Hanson Bridgett. Retrieved February, 2012, from www.hansonbridgett.com/Publications/pdf/ipd-teams-creation-organization-management.aspx.

Choi Granade, H., Creyts, J., Derkach, A., Farese, P., Nyquist, S., & Ostrowski, K. (2009). Unlocking energy-efficiency in the U.S. economy: *McKinsey & Company*. Retrieved June 2011 from www.nachi.org/documents/energy/US_energy_efficiency_full_report-McKinsey.pdf.

Gann, D., Wang, Y., & Hawlins, R. (1998). Do regulations encourage innovation? - The case of energy efficient housing. *Building Research and Information,* ***26****(4),* 280-296.

Ibrahim Rahinah, and Mark Nissen. (2005). Discontinuity in Organizations: Developing a Knowledge-Based Organizational Performance Model for Discontinuous Membership. *Collaboratory for Research on Global Projects Working Paper #0020*, Stanford University. Retrieved March, 2012, from crgp.stanford.edu/publications/working_papers/IbrahimNissen2.pdf.

Javernick-Will, Amy, Levitt, R. E., & Scott, W.R. (2007). Understanding Knowledge Acquisition, Integration and Transfer by Global Development, Engineering and Construction Firms. *Collaboratory for Research on Global Projects Working Paper #0028*, Stanford University. Retrieved March, 2012, from http://crgp.stanford.edu/publications/working_papers/Javernick%20Will.pdf.

Javernick-Will, Amy, & Scott, W.R. (2009). Who Needs to Know What? Institutional Knowledge and International Projects. *Collaboratory for Research on Global Projects Working Paper #0045*, Stanford University. Retrieved March, 2012, from

http://crgp.stanford.edu/publications/working_papers/Javernick-Will_Scott_Who_Needs_to_Know_What_WP0045.pdf.

Javernick-Will, Amy. (2008). The Institutionalization of Knowledge Management in an Engineering Organization. *Collaboratory for Research on Global Projects Working Paper #0040*, Stanford University. Retrieved March, 2012, from http://crgp.stanford.edu/publications/working_papers/Javernick-Will_Scott_Who_Needs_to_Know_What_WP0045.pdf.

Johnson Controls. (2010). Case study - Bank of America Plaza - Columbia, South Carolina. Johnson Controls. Retrieved February, 2012, from www.johnsoncontrols.com/content/dam/WWW/jci/be/case_studies/Bank_of_America_Case_Study.pdf.

Johnson Controls. (2012). Sustainability in Action. *Johnson Controls*. Retrieved February, 2012, from www.johnsoncontrols.com/content/us/en/about/our_company/featured_stories/glendale_campus_now.html.

Kampschroer, K. Pogue, D.L., Laquidara-Carr, D. (2011) Do Green Buildings Make Dollars & Sense. *CBRE.* Retrieved April, 2012, from http://catcher.sandiego.edu/items/business/Do_Green_Buildings_Make_Dollars_and_Sense_draft_Nov_6_2009.pdf.

Levitt, R. E., Wang, C.A., Ho, S.P., & Javernick-Will, Amy. (2011). A Contingency Theory of Organizational Strategies for Facilitating Knowledge Sharing in Engineering Organizations. *Collaboratory for Research on Global Projects Working Paper #0064*, Stanford University. Retrieved April, 2012, from http://crgp.stanford.edu/A%20Contingency%20Theory%20of%20Organizational%20Strategies%20for%20Facilitating%20Knowledge%20Sharing%20in%20Engineering%20Organizations%20.pdf.

Nam, C. H., & Tatum, C. B. (1997). Leaders and champions for construction innovation. *Construction Management and Economics, 15*(3), 259-270. doi: 10.1080/014461997372999.

Navarro, M. (2009, April 6). Empire State Building plans environmental retrofit. *New York Times Environment*. Retrieved February, 2012, from www.nytimes.com/2009/04/07/science/earth/07empire.html?_r=1.

Petroski, H. (1992). *The Evolution of Useful Things,* Vintage Books .

Sheffer, D.A. (2011). Innovation in modular industries, implementing energy-efficient innovations in US buildings. *Doctoral dissertation, Dept. of Civil & Environmental Engineering, D#021*, Stanford University.

Sheffer, D. A., & Levitt, R. E. (2010). How industry structure retards diffusion of innovations in construction: Challenges and opportunities. *Collaboratory for Research on Global Projects Working Paper 59*, Stanford University. Retrieved June, 2011, from http://crgp.stanford.edu/publications/working_papers/Sheffer_Levitt_how_industry_retards_diffusion_of_innovation_WP0059.pdf.

Sheffer, D. A., & Levitt, R. E. (2011). The diffusion of energy saving technologies in the building industry: Structural barriers and possible solutions. *Collaboratory for Research on Global Projects Working Paper 57*, Stanford University. Retrieved June, 2011, from http://crgp.stanford.edu/publications/working_papers/Sheffer_Levitt_Diffusion_of_Energy_Saving_WP0057.pdf.

Stinchcombe, A. (1959). Bureaucratic and Craft Administration of Production: A Comparative Study. *Administrative Science Quarterly, **4*** (Sep), 168-187.

Strunk, W., & White, E. B. (1979). *The elements of style*. New York: Macmillan.

Tatum, C. B. (1989). Organizing to Increase Innovation in Construction Firms. *Journal of Construction Engineering and Management, **115**(4),* 602. doi: 10.1061/(ASCE)0733-9364(1989)115:4(602).

Taylor, J. E. (2005). Three perspectives on innovation in interorganizational networks: Systemic innovation, boundary object change, and the alignment of innovations and networks. *Doctoral dissertation, Dept. of Civil & Environmental Engineering, D#012*, Stanford University.

Taylor, J. E., & Levitt, R. E. (2004). Understanding and managing systemic innovation in project-based industries. In: D.P. Slevin, D.I. Cleland and J.K. Pinto (Eds.), *Innovations: Project Management Research*, 83-99.

Tipping Mar. (2012). *Tipping Mar*. Retrieved February, 2012, from www.tippingmar.com.

Yin, R. K. (2009). *Case study research: Design and methods.* London: SAGE.

ZETA Communities - Welcome to Our Zero Energy Communities. (2011). *ZETA Communities.* Retrieved February, 2012, from www.zetacommunities.com.

Appendix A: Sample Email Appeal

Dear **NAME,**

My name is Anthony Clarke. I am an undergraduate and a graduate student in the Department of Civil and Environmental Engineering at Stanford University. Currently, I am working on my honors thesis research within Stanford's Collaboratory for Research on Global Projects on sustainable integration diffusion, specifically in commercial real estate.

I was referred to you by **NAME OF REFERRAL**, and recognize that you have been involved in **EXAMPLE OF COMMERICAL REAL ESTATE PROJECT**. I would really appreciate if we could set up a 15-20 minute appointment for a phone interview at your earliest convenience (preferably at the beginning of the work day, during lunch, at the end of the work day, or on the weekend).

Our discussion would cover the following:

- Your experience with sustainable buildings
- Determining why sustainability was or was not a priority in past projects
- Examining projects that successfully and unsuccessfully included sustainable measures
- Discussing how horizontal, vertical, or longitudinal integration benefit or retard the integration process

Please be reassured that the intentions of the interviews I am conducting are to distil industry trends and will never mention a specific person or company by name.

Again thank you for your time. I have included my contact information below. Please let me know if we can arrange a time for a discussion.

With Regards,

Anthony Clarke
M.S. Candidate | Civil Engineering 2012
B.S.H. Candidate | Civil Engineering 2012
ASCE President | Stanford Chapter
(630) 542–3643 | aclarke3@stanford.edu

Appendix B: Research Process and Method

Dear **NAME,**

Thank you for taking the time to talk with me on **DATE** at **TIME**. I know your time is valuable. Please be advised that your responses will be recorded and may be cited research as a part of my Honors Thesis or for ongoing research in Stanford's Collaboratory for Research on Global Projects. Your name, the company you work for, and any company/people that you refer to will never be used in the published research. Please be reassured that the intentions of the interviews I am conducting are to distil industry trends and will never mention a specific person or company.

Attached is a list of questions intended to guide our conversation on how sustainable innovations are making their way into commercial buildings. However these questions are merely a template. Please feel free to stop and tell me stories about your experiences at anytime during the conversation or to provide information you feel relevant to our conversation.

Again thank you for your time. I have included my contact information below. Feel free to contact me at any time with questions, comments, or concerns.

With kind regards,

Anthony Clarke
M.S. Candidate | Civil Engineering 2012
B.S.H. Candidate | Civil Engineering 2012
ASCE President | Stanford Chapter
(630) 542–3643 | aclarke3@stanford.edu

Appendix C: Interview Questions

General Industry Background

1. Please describe the extent of your experience *designing/developing/investing in* commercial real estate buildings.
2. Please describe the role/roles you have played in the *design/development/investment* process.
3. Who typically dictated the final *design/development/investment* strategy of the buildings?
4. If not yet specified, what types of commercial buildings have you been a part of?
5. How often and how heavily was the building's sustainability emphasized in these projects? In what phases?

Cases with Sustainable Innovations Considerations

6. Why was it considered and whose choice was it? Was it a LEED building?
7. What aspects of sustainability were considered?
    - Sustainable construction process (low waste, local procurement, etc.)?
    - Sustainable building materials? Renewable energy (PV or wind turbines)?
    - Low energy use (sustainable windows, day lighting, centralized building controls, etc.)?
    - Low water use (waterless urinals, recycled grey water, etc.)?
8. Were reductions in life cycle costs a significant factor — why or why not?
9. Did the scale or duration of the project play a factor in the decision?
10. Were contractual incentives or requirements in place to encourage sustainable practices? How effective were these measures?
11. Were sustainable alternatives ever desired by the client and/or specified by the designer that was not delivered in practice?
12. In what cases were sustainable measures incorporated successfully? Unsuccessfully?
13. Does your firm have a vested interest the long-term performance of the building?

Cases without Sustainable Innovations Considerations

14. Why was it not considered? Whose final decision was it?
15. Was any party a proponent of sustainable alternatives? Was it a LEED building?

Industry Integration/Fragmentation

16. Does your firm ever engage in joint ventures, alliances, or partnerships with other companies in different nodes of the supply chain that would encourage sustainable efforts? (vertical integration) Why or why not?
17. Does your firm ever engage in joint ventures, alliances, or partnerships with other companies in the same node of the supply chain that would encourage sustainable efforts? (horizontal integration) Why or why not?
18. Does your firm keep record of sustainable efforts so that information can be passed from project to project? (longitudinal integration) Why or why not?

<u>Conclusion</u>

19. Do you mind if I continue to stay in touch with you throughout the course of my research process?
20. Is there anyone else either within your company or outside of your company that you would refer me to for further research?

Appendix D: Sample Follow-Up

Dear **NAME**,

It was a pleasure talking to you on **TIME**. Thank you very much for your time and expertise. I will continue to stay in touch throughout the process and make sure to send you a final version of my work.

Please feel free to contact me at anytime if there is anything additional you would like contribute, anyone else who you feel would provide a new or interesting perspective to my continued research, or any comments you might have.

Once again, I know your time is valuable. Thank you for taking time out of your schedule for my research.

Appreciatively,

Anthony Clarke
M.S. Candidate | Civil Engineering 2012
B.S.H. Candidate | Civil Engineering 2012
ASCE President | Stanford Chapter
(630) 542–3643 | aclarke3@stanford.edu