CHAPTER 1

What Would Make Us Proud?

"You're here because you know something. What you know you can't explain, but you feel it. You've felt it your entire life, that there's something wrong with the world. You don't know what it is, but it's there, like a splinter in your mind, driving you mad."

—Morpheus, *The Matrix* (1999)

1.1 CURRENT STATE OF FACILITY PERFORMANCE

Buildings should perform to or even exceed our expectations. We should be able to set high standards during design that are met during operations and use. We have some success defining and predicting first cost, design-construction duration, and structural and water-tightness performance. Project teams often achieve desired performance for these objectives today. Facilities don't tend to fall down—they tend to keep the water out, and they tend to be delivered on time and on budget, although achieving all of these goals simultaneously is somewhat less common. But when we include other project goals, it is far less common that project teams meet them.

Consider, for example, building energy performance. This operational parameter is particularly significant to life cycle cost, sustainability, and carbon emissions and affects user comfort and functionality. A variety of modeling tools exist to predict performance during the design phase; yet it is rare that a building performs during the use phase as simulated during design.

A recently completed building at Stanford University exemplifies this issue. It has better energy performance than buildings of similar size and function, but, in the first years of operation, used significantly more energy than the design team projected during the design phase (Kunz, Maile, & Bazjanac, 2009). The difference between projected and actual performance is caused by operational inefficiencies (which have been and are being corrected), by unrealistic or unconfirmed assumptions in building use, changes in use of some of the spaces to more energy-intensive activities that were not incorporated into the building energy performance simulations, and shortcomings of the energy simulation and prediction tools. Even though the building performs relatively well, the project team did not meet the aggressive energy performance goals set during design or, at least, failed to notify the users and the client that actual energy use would be above expectations. Hence, the building owners and users were surprised by the lower than expected energy performance.

Unfortunately, the literature reports similar experiences for other buildings for which well-organized clients with lots of design, construction, and operations experience hired very strong design and construction teams, yet failed to achieve the energy performance goals set during the project's design (Scofield, 2002, 2009).

Nilsson and Elmroth's (2005) analysis of 23 retrofitted buildings in the Malmö project revealed three main reasons for the poorer than expected energy performance: (1) vendors indicated overly optimistic window performance, that is, the window calibration in the vendor's laboratory characterized the windows too optimistically with respect to their insulation performance in the context of the actual buildings; (2) the energy analysis program did not consider thermal bridges properly; and (3) the buildings leaked too much air, largely due to tolerances in the structural and façade systems that did not create a building envelope that supported the aggressive energy performance targets.

It could, of course, be that these examples of the performance of individual projects are isolated aberrations of otherwise strong performance. The accounts of the performance of buildings and infrastructure on larger scales suggest otherwise.

A study by the American Physical Society (APS) concludes that buildings that follow the LEED (Leadership in Energy and Environmental Design) guidelines for green buildings (U.S. Green Building Council [USGBC], 2002) don't end up, on average, having better energy performance than buildings that don't follow the LEED guidelines (APS, 2008). As a final example in a potentially much longer list of far from sustainable performance of the built environment, in the United States, energy that went into making the materials that end up as construction and demolition waste each year—which is the largest contributor to landfills—is, according to our rough calculations, about equivalent to the electricity California uses each year. In other words, each year the U.S. construction practices throw away materials with embodied energy content equivalent to the electricity used in California. And it is not just energy performance that is suffering. The American Society of Civil Engineers (ASCE) has been giving poor grades for the state of the infrastructure in the United States for many years (ASCE, 2009). Walter Podolny and others report about several bridges that had to be retrofitted or rebuilt after just 20 or 30 years of service in Europe (Podolny et al., 2001), which is a life cycle performance and durability that is lower than society typically expects from infrastructure projects.

In summary, the experience of well-intentioned facility owners and highly capable design and construction teams and the accounts of the performance of built facilities from various sectors of the industry and various parts of the world suggest that today's approaches to delivering and operating constructed facilities do not give us what we want. Just consider the well-documented high impact of the built environment on energy consumption, emissions of carbon dioxide (CO_2) and other greenhouse gases (GHGs;), (National Science and Technology Council [NSTC], 2008), contributions to landfills, and so on.

Although better software and measurement tools would be welcome, we believe that the fundamental problem lies in how design, construction, operation, and use are integrated. In most cases, we do not fully use our human assets and fail to organize information and work into an optimized flow. Unless we do so, we will continue to be surprised and disappointed by building performance and will forfeit the opportunities created by better models and visualization tools. We need to change. Building owners should take a hard look at the performance of their facilities, and service providers (architects, engineers, builders, etc.) should thoroughly consider the impact of their current practices and then develop an inspired and inspiring strategy for dramatically higher-performing facilities. Only then can we achieve the performance we predict and the buildings we deserve.

1.2 WHAT IF?

What if every building and every piece of infrastructure truly worked? What it they were all designed not simply to fill a need, but to enhance our way of life? What if they were finished on time and on budget, without doing harm to people or the environment? What if every building performed as highly as possible, with all systems working in concert to support its purpose? But they don't. And those of us in the architecture, engineering, and construction (AEC) industry know that something isn't right.

The AEC industry is responsible for building the world's physical wealth,[1] from truly magnificent structures to modest dwellings. The industry is arguably one of the oldest in the world, and many people come to it for deeply personal reasons, a long family tradition, or an inspiring experience. This field attracts motivated, incredibly hardworking professionals—early risers who work in rain, snow, and heat, and who believe it is one of the best industries in the world. The problem isn't the people; it is how they and their work are organized.

In just the past 20 years, buildings and infrastructure have become vastly more complex than they were for most of human existence. Advances in mechanical, electrical, plumbing, conveying, information, and other systems have led to rapidly increasing specialization, dramatically increasing the coordination required to engage the many specialists in a timely, efficient, and effective manner. Construction projects also suffer from variability, unpredictability, and uncertainty, such as which specific system will eventually be selected, who is involved in the building process, how facilities and their systems and parts are produced and assembled, and a host of external factors such as weather, market conditions, and so on. Each project brings together a different set of players who might or might not have worked together before; every project is unique in some way.

Despite our very best efforts, we consistently end up with a product that satisfies few, including ourselves. In almost every building, a well-meant shortcut is taken somewhere during design, construction, or operation that results in a product that is less than the original vision, and less than what the users actually require. Too many projects squander time, money, energy, labor, materials, knowledge, and other precious resources largely because of how they are organized and carried out; too often, the AEC industry is characterized by unmet expectations (KPMG, 2015). Owners and project participants are, of course, aware of this track record. Sadly, we see many project organizations set up to avoid failure, which is seen as a success, instead of striving to create a great building that sustains its users in their endeavors.

When we look critically about the process used to deliver a building, we see a huge amount of fragmentation. In an attempt to tackle highly complex problems, the industry has responded by breaking projects into small, isolated pieces, and focusing on producing each of those at the lowest possible cost. But we rarely, if ever, consider how to put all these pieces together over time to create the best building possible by thinking about how a team is organized, how information flows within a project, or how to define the vision and goals of the project and keep them alive for its duration. We keep our sights on the bits and pieces rather than raising our eyes to the project as an integrated whole. For those of us who have spent our careers in the industry, it seems hard to believe that so many projects are delivered in such a shockingly suboptimal way. And yet, many of us have had a sneaking feeling all along that there must be a better approach. We see workers idle for lack of materials, materials pile up in parking lots with no one to install them, hundreds of thousands of dollars in rework due to poor planning or late or incomplete communication. In the end, we see a building that costs more to operate than it should, and doesn't meet the owner's and users' original vision.

The knowledge and experience of each professional and each company is not integrated in a consistent and timely manner, and consequently innovative ideas and opportunities—which could lead to creating a better building—are missed, overlooked, or ignored. Current contractual agreements, rather than reinforcing the need to bring the team members together to create innovative solutions, drive them apart to work in independent silos. It should come as no surprise that the current organization and process often lead to an adversarial relationship between the parties, rather than a relationship of cooperation and coordination. Too often, the focus is on short-term opportunities, which rarely yield the best choices for the project as a whole.

For example, on one bridge project, the owner and the design team decided to concentrate on a single design option to shorten the design period and allow construction to start at the earliest date. This approach caused the team to overlook an alternative design that could have dramatically reduced the construction time while also improving safety for the workers and the ship traffic that passes below the bridge. Shortcutting design to accelerate schedule meant the design ultimately had to be drastically modified, which cost the owner redesign and review time—squandering some of the benefits of the improved design.

Figure 1.1 shows the bridge being built with the modified design. The first design called for the bridge deck between the support piers to be cast in situ. That method would have been much more

FIGURE 1.1 Prefabricated box girder deck being set in place. Courtesy of Michael Veegh.

expensive to build, compared to precast box girders that can be assembled on land and then floated out to the bridge and lifted in place. The second option (using the precast box girders) is what the team eventually adopted, but only after time and money were lost pursuing the initial design.

What if we could create buildings that actually exceed expectations, instead of fall short? What if we could finish projects on time and under budget, with no harm, and no rework? What if we could produce a building that is beautiful, efficient, useful, and cost effective, all at the same time? We have come to accept less than this, but we don't have to. What we physically construct may well be our most permanent and lasting legacy, and it should be something we are proud of.

We believe that an integrated approach is the most promising strategy to produce a truly high-performance building. Through harnessing the talents of many individuals from different disciplines, creatively shaped incentives, working collaboratively, and sharing knowledge, we can produce long-lasting value for owners and occupants. Figure 1.2 shows the result of the integrated UCSF Mission Bay Hospitals project team's effort to produce a product—in this case a patient room headwall—that integrates architectural, structural, mechanical, electrical, plumbing, and medical features and that is buildable and operable and effectively serves its final customer, the patient.

On the UCSF Mission Bay Hospitals project, the team decided early on (in Design Development) to prefabricate headwalls in patient rooms off site. They did this because headwalls are complex, composed of many different systems, including high and low voltage, mechanical, data, medical gas, and so forth. Project foremen explained the many things that could go wrong in installing and testing the many utility systems that make up each headwall. Offsite fabrication meant they could build and test utilities in a controlled environment and simply pop the complete wall into place on site.

Although we can avoid an integrated process, we can't avoid interactions. Once built, every building functions as a whole with technical systems that are either supporting or fighting each other. But we can also choose to produce buildings with highly integrated systems by using teams and integrated work processes. The aim of this book is to describe and explain how to set up and manage projects in such an integrated way.

1.3 A WAY FORWARD

Essentially, an integrated team operates as a virtual organization committed to the project. It is not organized to optimize the outcome of individuals or their companies. The integrated team allocates resources and makes decisions guided by the core project values. Ideally, it is a synergistic system that is greater than the sum of its parts, built on the assumption that major building projects are not inherently a zero-sum game; it is possible for everyone involved to win together.

Integrated project delivery (IPD) has several major components. At the outset, owners will define their values and goals so that the entire team can understand, quantify, and track what they are working toward. Next, an organizational structure is created and planned intentionally to enable good work. The organization emphasizes cross-functional teams at a working level; transparency and information

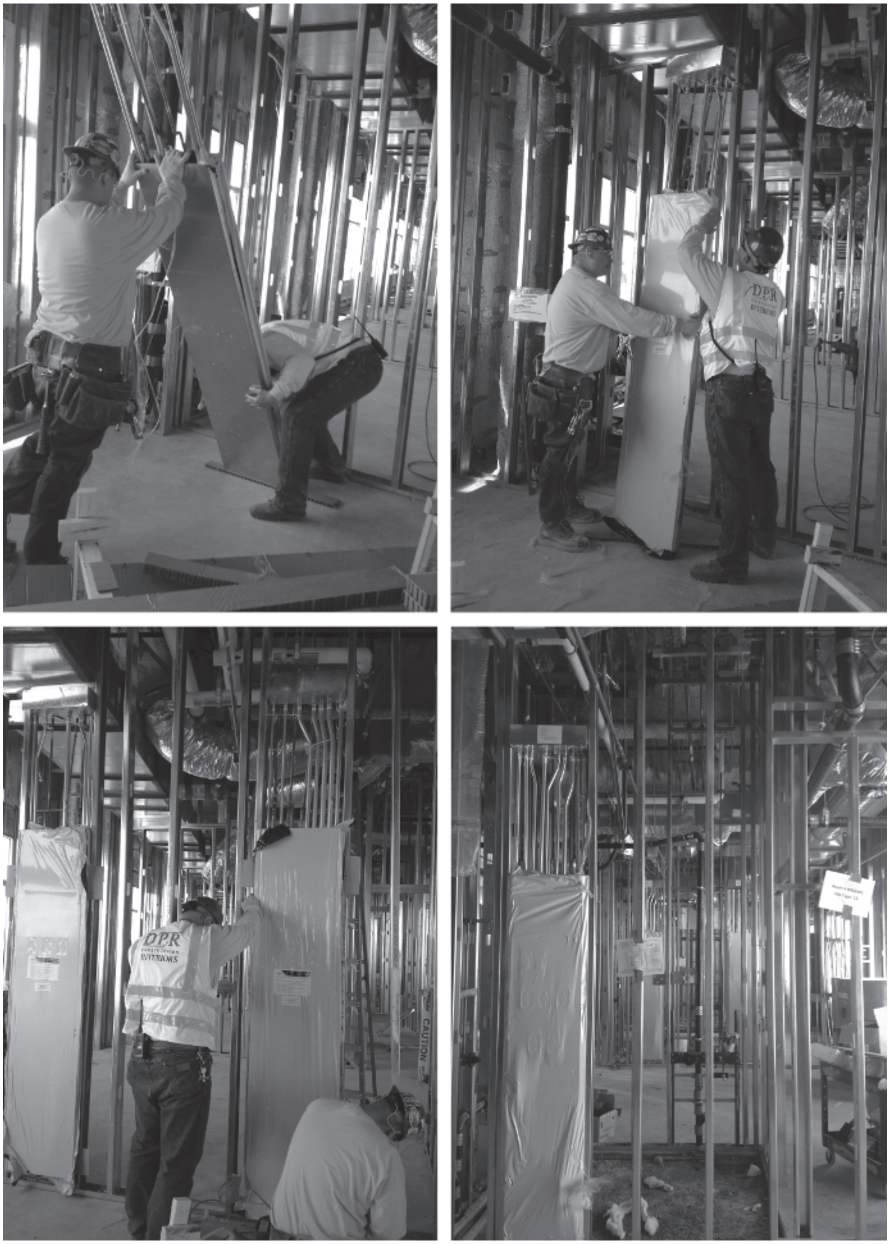

FIGURE 1.2 Headwall installation. Licensed by The Regents of the University of California on behalf of its UCSF Medical Center; courtesy of DPR Construction.

flow; swift identification of problems, response, and adaptation to them; and decision making as close to the frontline as possible.

Coupled with the structure is a physical place to work, which encourages desired team behaviors and makes them possible. The physical space allows face-to-face interaction, builds enduring relationships, enables questions to be answered rapidly, promotes personal accountability, and vastly increases information sharing so that every team member stays on the same page. Finally, work practices that include a high degree of collaboration, simulation, and visualization enable the right work to be done the right way, and built just once. Meaningful metrics, displayed through a project dashboard, gives each team member the real-time information necessary to know how the project is performing and to take steps to improve.

This book delves into the fundamental concepts of integrating project delivery. We discuss how to set up an organization and processes that best leverage each discipline's knowledge and experience to deliver a building that meets or exceeds the owner's goals; in other words, set up an organization focused on achieving a successful project, not an organization set up to avoid failure. We also outline how to set up the various roles and responsibilities of the project participants and create a true team culture, along with the skills that designers, engineers, and contractors need to develop to effectively and efficiently integrate their projects.

While the AEC industry has been abuzz for some time about the potential rewards of an integrated delivery approach, many firms now show signs that they have the capacity and capability to make IPD a reality (Bell, 2012). We truly believe that our industry could be on the brink of a historic shift, but it will take the audacity, fearlessness, and conviction of thousands of boots on the ground to make it happen.

Integration Results

The Lean Construction Institute recently sponsored research conducted by Dodge Data & Analytics to benchmark owner satisfaction and project performance and the effect of Lean principles on project outcomes. Along the way, the research team also looked at how project delivery methods compared (Mace, et al., 2016).

The researchers sent questionnaires to 81 owners, covering 162 projects. An additional 10 IPD projects were studied in detail in a team led by Renée Cheng (Cheng, et al., 2016). The owners were asked to separate their projects into typical versus best project. Figure 1.3 displays their findings regarding project delivery type.

Neither the "typical" nor the "best" columns sum to 100% because the researchers excluded project delivery types that did not achieve 20% of the sample size. The importance of the data lies in the difference in columns for a given project delivery type. In design-bid-build, it was almost four times more likely that a project would be "typical" rather than "best." Construction management at risk fared better, although still did not have an even likelihood of success. Design-build is significantly more likely to result in a "best" project. The star of the study, however, was Integrated Project Delivery, which was over 20 times more likely to result in a "best" project.

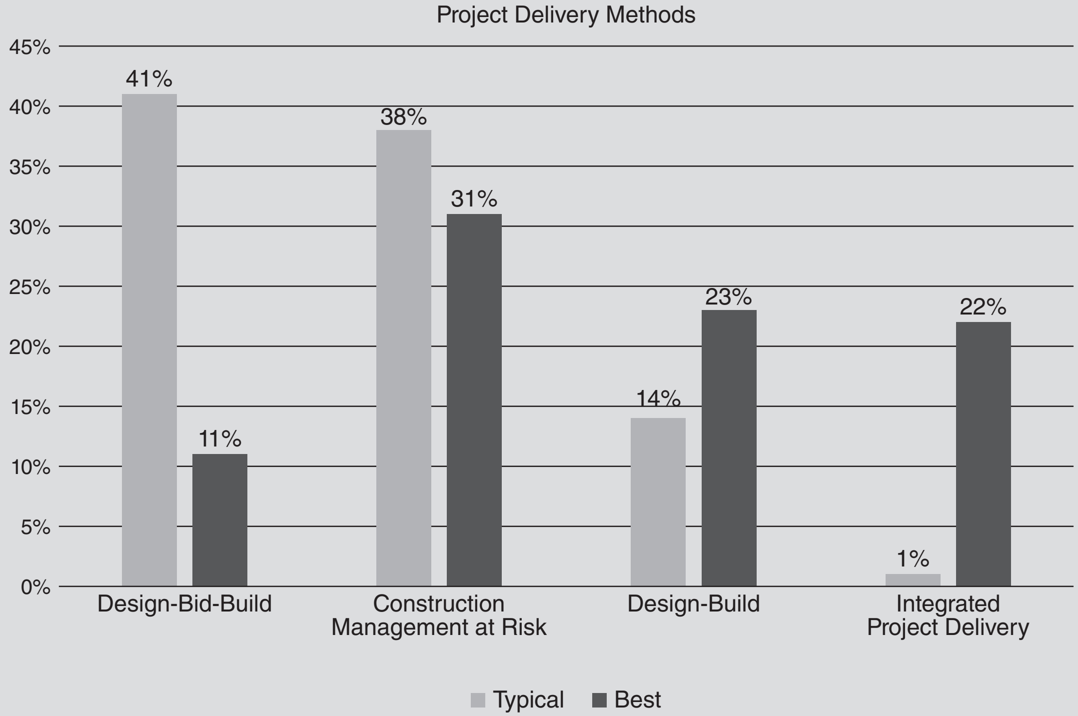

FIGURE 1.3 Comparison of project delivery methods. Courtesy of Lean Construction Institute.

This study is consistent with prior work by the research team led by Renée Cheng that published data based on IPD project participants' perceptions of the value of IPD as compared to their experience with other project delivery types (Cheng, et al., 2015).

The Dodge researchers reported several interesting relationships between Lean practices and "best" project outcomes. First, they found that in 76 percent of the "best" projects, the key project team members, including trades, were engaged during conceptual design or earlier. In contrast, only 34 percent of the "typical" projects had engaged the key project members by that time. They also looked at Lean methods and found that all of the Lean methods studied were used at least twice as much on "best" than on "typical" projects. Their results are particularly striking with regard to target value design (40 percent "best," 6 percent "typical") and use of co-location (44 percent "best," 6 percent "typical"). The Dodge results strongly complement the recommendations in this book as to the use of integrated project delivery, target value design, co-location, and production management tools.

This is not to say that integrating project delivery is easy—change rarely is. As one senior IPD project manager said, at first, you feel like you are continually failing. The team seems to be constantly finding problems, and it may seem easy to get discouraged or get the impression that a traditional process runs more smoothly. The fact is that the issues that surface early in IPD will eventually come to light on any project. But when they do, it may be too late to implement elegant and efficient solutions. IPD forces problems into the light, and enables the team to address them before they get worse.

Yes, IPD can be difficult, but the reward is that the resulting product should be superior, with little room for suboptimization. IPD thrives on exchange of ideas and information, which are often in conflict with each other; it is a challenging environment for many people to work in. However, the current process is extremely unsatisfying and frustrating and lets us be, essentially, lazy. An integrated approach may be more demanding, but ultimately, it is more fulfilling.

At the end of the day, would we be proud to tell our children that we helped create millions of tons of waste[2] or that we helped design and build a building that's merely adequate, or that someone died while working on our project,[3] or that we helped create a building that's sufficient now, but will be obsolete in 10 years? We believe the AEC industry can and must do much better—and an integrated approach offers the best blueprint to do that.

NOTES

1. We are indebted to our colleague John Kunz, a computer scientist, for pointing out this important fact to us.
2. The EPA estimated that the United States generated 170 million tons of construction and demolition waste from construction, demolition, and renovation for nonresidential and residential buildings in 2003 alone, equal to 3.2 pounds of building-related materials waste per capita per day (USEPA, 2009).
3. According to the Bureau of Labor Statistics, 798 workers were killed on the job in the construction industry in 2011—over 14 people per week (USDOL, 2011).

REFERENCES

American Physical Society (APS). (2008). *Energy future: Think efficiency*. Retrieved October 4, 2010, from http://www.aps.org/energyefficiencyreport/report/aps-energyreport.pdf.

American Society of Civil Engineers (ASCE). (2009). *Report card for America's infrastructure*. Retrieved October 4, 2010, from http://apps.asce.org/reportcard/2009/grades.cfm.

Bell, J. (2012, August 10). Designers and contractors try out integrated project delivery, Portland Business Journal. Retrieved on October 8, 2016, from http://www.bizjournals.com/portland/print-edition/2012/08/10/designers-and-contractors-try-out.html.

Cheng, R., Allison, Markku, Sturts-Dossick, C. Monson, C, (2015) *IPD: Performance, Expectations, and Future Use: A Report On Outcomes of a University of Minnesota Survey*. University of Minnesota. Retrieved October 16, 2016, from http://ipda.ca/site/assets/files/1144/20150925-ipda-ipd-survey-report.pdf.

Cheng, R., Allison, M., Sturts-Dossick, C., Monson, C., Staub-French, S., Poirier, E., (2016). *Motivation and Means: How and Why IPD and Lean Lead to Success,* University of Minnesota. Retrieved from http://arch.design.umn.edu/directory/chengr/.

KPMG, *Climbing the curve: 2015 global construction project owner's survey*. Retrieved February 28, 2016, from https://www.kpmg.com/BR/PT/Estudos_Analises/artigosepublicacoes/Documents/Build-Construction/global-construction-survey-2015.pdf.

Kunz, J. (2010, September 16). *VDC for sustainable facility design, construction, and operation*. Presentation at CIFE-SPS VDC Certificate Program Introductory Course, Center for Integrated Facility Engineering (CIFE), Stanford, CA.

Kunz, J., Maile, T., & Bazjanac, V. (2009). *Summary of the energy analysis of the first year of the Stanford Jerry Yang & Akiko Yamazaki Environment & Energy (Y2E2) Building*. Technical Report #183, Center for Integrated Facility Engineering, Stanford, CA.

Mace, B., Laquidara-Carr, Donna, Jones, S. (2016). *Benchmarking Owner Satisfaction and Project Performance.* Retrieved from http://www.leanconstruction.org/learning/.

National Science and Technology Council (NSTC). (2008, October). *Final report: Federal research and development agenda for net-zero energy, high-performance green buildings*. National Science and Technology Council, Committee on Technology, Subcommittee on Buildings Technology Research and Development. Retrieved October 7, 2010, from http://www.bfrl.nist.gov/buildingtechnology/documents/FederalRDAgendaforNetZeroEnergyHighPerformanceGreenBuildings.pdf.

Nilsson, A., & Elmroth, A. (2005). The buildings consume more energy than expected. In *Sustainable city of tomorrow: B01—Experiences of a Swedish housing exposition* (pp. 107–118). Stockholm, Sweden: Formas.

Podolny, W., Cox, W. R., Hooks, J. M., Miller, M. D., Moreton, A. J., Shahawy, M. A. … Tang, M.-C. (2001). *Performance of concrete segmental and cable-stayed bridges in Europe*. Report FHWA-PL-01-019, Office of International Programs, Office of Policy, Federal Highway Administration, U.S. Department of Transportation. Retrieved October 4, 2010, from http://international.fhwa.dot.gov/Pdfs/conc_seg_cabstay_euro.pdf.

Scofield, J. H. (2002). Early energy performance for a green academic building. *ASHRAE Transactions, 108* (Part 2), 1214–1230.

Scofield, J. H. (2009). Do LEED-certified buildings save energy? Not really… *Energy and Buildings, 41,* 1386–1390.

U.S. Department of Labor, Bureau of Labor Statistics (USDOL). (2011). *Revisions to the 2011 census of fatal occupational injuries (CFOI) counts*. Retrieved from http://www.bls.gov/iif/oshwc/cfoi/cfoi_revised11.pdf.

U.S. Environmental Protection Agency, Office of Resource Conservation and Recovery (USEPA). (2009). *Estimating 2003 building-related construction and demolition materials amounts*. National Service for Environmental Publications, EPA530-R-09-002.

U.S. Green Building Council (USGBC). (2002). *Green building rating system for new construction and major renovations* (LEED-NC), Version 2.1. Retrieved October 4, 2010, from http://www.usgbc.org/Docs/LEEDdocs/LEED_RS_v2-1.pdf.