RESEARCH

DELIVERY PROCESS ATTRIBUTES, COMMON TO INDIA AND THE U.S., FOR MORE SUSTAINABLE BUILDINGS

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ABSTRACT

India is a rapidly developing nation, so its adoption of sustainable building would have considerable social, environmental, and economic benefits. However, process attributes that contribute to successful delivery (planning, design, construction and operation) of sustainable buildings in India are largely undefined. Other projects in India would benefit from a rigorous identification of these process attributes, which is the purpose of this research. This research applies process mapping to study the delivery of Soundarya Decorator's factory building in Chennai, India; a project which achieved advanced sustainability performance with no first cost increase. From these process maps, process attributes are identified and compared to those identified in a previously published study of Toyota's South Campus facility in Torrance, California. Process attributes common to both projects include: demonstrating an early commitment to sustainability by key stakeholders; setting goals related to sustainability, not certification; continuously educating project stakeholders on sustainability; aligning sustainable features with business objectives; encouraging project team "buy-in" to sustainability goals; and investing design time to consider alternative sustainable solutions.

KEYWORDS

sustainable development, project delivery, India, buildings

INTRODUCTION

Current building practices are not sustainable. For example, buildings use more nonrenewable fossil fuels than any other industry sector and contribute a proportional amount of climate-changing CO_2 emissions (US Department of Energy 2007). Recognizing these issues, nations worldwide are revising their building practices with greater sustainability in mind. As a rapidly developing nation, India has an opportunity to "leapfrog" directly to sustainable building practices that seek to optimize social, environmental, and economic impacts. Leapfrogging occurs when nations implement state of the art strategies and technologies without going through the intermediate steps taken by other nations to reach the same point. Widespread cell phone use in Africa, in place of developing a landline infrastructure, is an example of leapfrogging.

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More sustainable building practices in India would improve the long-term viability of the countries development, reduce dependence on fossil-fuels, and limit CO_2 emissions. in India are not well defined. Defining key attributes of delivery processes (planning, design, construction and operations) for sustainable building is a required step for their more widespread adoption in India. In turn, widespread adoption of these attributes is a required step for more sustainable buildings. The goal of this research is to help facilitate leapfrogging of sustainable building in India by identifying process attributes for an effective sustainable building project in India and comparing these attributes with those identified for an effective sustainable project in the U.S.

BACKGROUND—SUSTAINABLE BUILDING PROCESSES

Planning, design and construction of a building involves a range of stakeholders (e.g., architects, engineers, construction managers, owners, occupants, and government agencies) performing various processes. For more sustainable buildings, there is added unfamiliarity and complexity in these processes (Hill and Bowen 1997; Reed and Gordon 2000; Lapinski et al. 2006). New stakeholders (e.g. commissioning agents, energy modelers) are involved. Traditional stakeholders have new roles (e.g. building operators have increased design input). New processes, such as energy modeling and enhanced commissioning, are added.

Planning, design, and construction processes for sustainable buildings can impact their costs and, as a result, their market penetration (Mogge 2004). For instance, buildings are achieving significant sustainable objectives with negligible or no first cost premiums (Kats 2009; Matthiessen and Morris 2007). Further, exemplary sustainable buildings *produce more energy than they consume* at minimal first cost premiums, which are quickly offset by energy cost savings (Lewers 2008). Still, many sustainable building projects experience a significant first cost premium, which inhibits more widespread adoption of sustainable buildings.

As is the case with traditional buildings (Konchar and Sanvido 1998), a contributing factor to the varying levels of cost-effectiveness for sustainable buildings is the effectiveness of their delivery processes (Yudelson 2008). Researchers have examined impact on sustainability outcomes of the overall structure of the delivery process comparing, for example, design-build projects with design-bid-build projects. Findings from this research indicate that this overall structure is less important than more specific delivery process attributes (Korkmaz et. al, 2010; Molenaar et. al. 2009; Bilec and Ries 2006).

Increased integration is recognized as a valuable attribute for sustainable projects and increasingly this attribute is a focus throughout the delivery process (Yudelson 2008). This integration enables the intricate, multidisciplinary collaboration between a wide range of stakeholders that helps generate sustainable solutions (Vanegas 2003). For example, an architecture firm may work alone on the schematic design for a traditional project. However, for a sustainable project seeking to maximize energy performance, the architect must closely coordinate their schematic design effort with groups, including mechanical engineers, facilities managers, building occupants, and utility companies. Process transparency helps facilitate this required integration by making the process, including status, goals and rules, visible to all stakeholders (Klotz et al. 2009).

A need remains to identify other process attributes that lead to successful sustainable projects. In particular, there is limited knowledge of these process attributes for projects in India. This research is designed to help address these needs.

FIGURE 1. The Soundarya building.

RESEARCH APPROACH

This research investigates process attributes for a factory and office complex (Figure 1), located in Kollathur, Chennai, India, for the interior design firm Soundarya Decorators. Specific elements of the Soundarya project are outlined in Table 1 along with a description of why these elements are more sustainable than a typical project. Elements of the project have sustainability benefits that include reducing heating and cooling needs, providing these services more efficiently, conserving water, minimizing material use, and reducing maintenance needs. These elements are described in Table 1 as examples of how this building achieves more sustainable performance than a traditional building. However, the focus of this research is not on specific sustainable building elements. Rather, this research identifies delivery process attributes that contributed to effective implementation of these sustainable elements.

Process Mapping as a Research Tool

An appropriate method to investigate process attributes for the Soundarya project is process mapping, which is a proven approach for identifying process attributes in a range of fields, including sustainable building delivery (Klotz et al. 2007; Lapinski 2005). Process maps help represent, study, and improve processes (Curtis et al. 1992). These maps act as visual aids for picturing work processes, showing how inputs, outputs and tasks are linked. Various process mapping methods have been used to study building processes (Austin et al. 1999; Papalambros and Wilde 2000; Tzortzopoulos et al. 2005). A tested mapping protocol for studying sustainable project delivery is applied to map the delivery processes for the Soundarya project

TABLE 1. Selected Soundarya building elements that are more sustainable than a typical project.

Project element	Sustainability impact
Natural ventilation and reduction of solar heat gain	Minimize cooling needs
Solar-thermal, parabolic trough, heating system	Heat more efficiently, with fewer CO_2 emissions
Solar-thermal vapor absorption chiller (powered by the heat from the solar-thermal system)	Cool more efficiently, with fewer CO_2 emissions
Hybrid wind and photovoltaic system to pump water for domestic supply	Move water more efficiently, with fewer CO_2 emissions
Rainwater management, grey-water recycling, and black-water treatment	Conserve water
Light colored roof with large overhangs	Reduce solar heat gain to minimize cooling needs; Eliminate gutters and downspouts
Eliminate unnecessary doors, windows, and side cladding	Reduce material
Form-finished concrete walls	Eliminate plaster and paint; Minimize required maintenance
Curved roof shape	Reduce material (enabled spanning with a shallower, lighter portal)

(Klotz et al. 2007). This protocol is a hybrid between the IDEF0 methodology, which is a series of diagrams first showing processes at a high level and then decomposing them into a series of sub-processes (Feldmann 1998), and Value Stream Mapping (VSM), which is a mapping methodology based on lean principles that originated in manufacturing and demonstrates the "big picture" of total process flow while enabling identification of value and waste (Rother and Shook 1998). The IDEF0 influence allows representation of the details (including relevant stakeholders) of the incremental decision processes and the VSM influence means that the protocol can also represent the interrelationships between all decisions.

In this research, the process maps are divided into 3 levels of detail (Lapinski 2005). The first level describes the overall phases of the building project, showing the big picture view essential to VSM. The second level shows the functional flows between the phases. The third level shows detailed flows for the inputs, activities, and outputs.

Process Map Development

Following the established mapping protocol, the process maps were developed through interviews with Soundarya project participants. Semi-structured interviews are used in this study as they allow the researcher to ask questions that could lead to continued conversation and additional or new qualitative data (Yin 1999, Fellows and Liu 1998). This approach enables a more complete understanding of the delivery process.

The semi-structured interviewing approach to developing the process maps was as follows:

1. An initial interview session was held with the chief architect, who also led the project management for the Soundarya Project. The goal for this session was to understand how value was defined for this project. Based on review of project documentation, clarification from the chief architect, and confirmation from the owner, the value definition for the Soundarya project is to build an "easy to maintain building that optimizes economic output and minimizes environmental damage." This value definition informs the rest of the delivery process.

2. After value was defined, another interview session was held with the chief architect to develop the Level 1 map, which consists of five general phases common to most building projects: planning, design, construction, post-construction, and post-occupancy.
3. For each phase in the Level 1 map, separate sessions with the owner, the architect, and their subconsultants were held to identify the process flow and project participants. All of these sessions were in person with the exception of the sessions with Soundarya's owner representative, who was in a different location and provided input primarily through e-mail.
4. A rough draft of the resulting Level 2 and 3 process maps was prepared by the researcher to encourage participant changes and feedback. These maps were then sent to the architect, owner, and subconsultants[1].
5. A follow-up session was held with architect, owner, and subconsultants to obtain and discuss their feedback on the draft Level 2 and 3 process maps.
6. Based on this feedback, the process maps were revised by the researcher and verified by the architect, owner, and subconsultants.

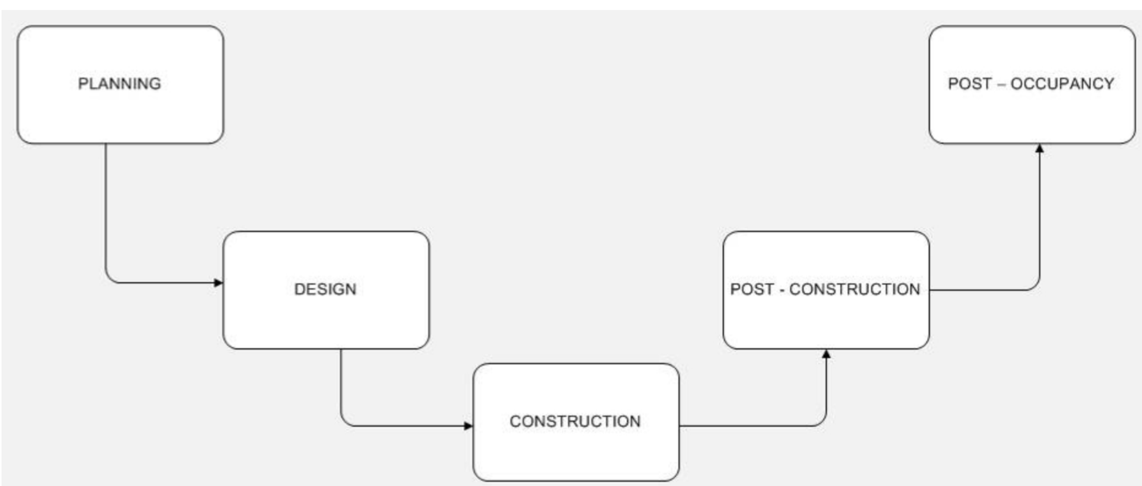
RESULTS AND ANALYSIS

The research approach yielded process maps and process attributes for the Soundarya project. To help facilitate leapfrogging of sustainable building in India, the process attributes identified for the Soundarya project were compared to process attributes for a sustainable project in the U.S., Toyota's south campus facility in Torrance, California.

Process Maps for the Soundarya Project

Figure 2 shows the Level 1 process map, which provides the macro-level view of the entire delivery process for the Soundarya project. This very basic map allowed the interview subjects to orient the Level 2 and 3 processes within the bigger picture of the Level 1 processes.

FIGURE 2. Level 1 Map.



[1]Expanding this research with information from other participants (e.g. contractors) could add these other perspectives to the process maps.

FIGURE 3. Level 2 and 3 map of the planning phase for the Soundarya project.

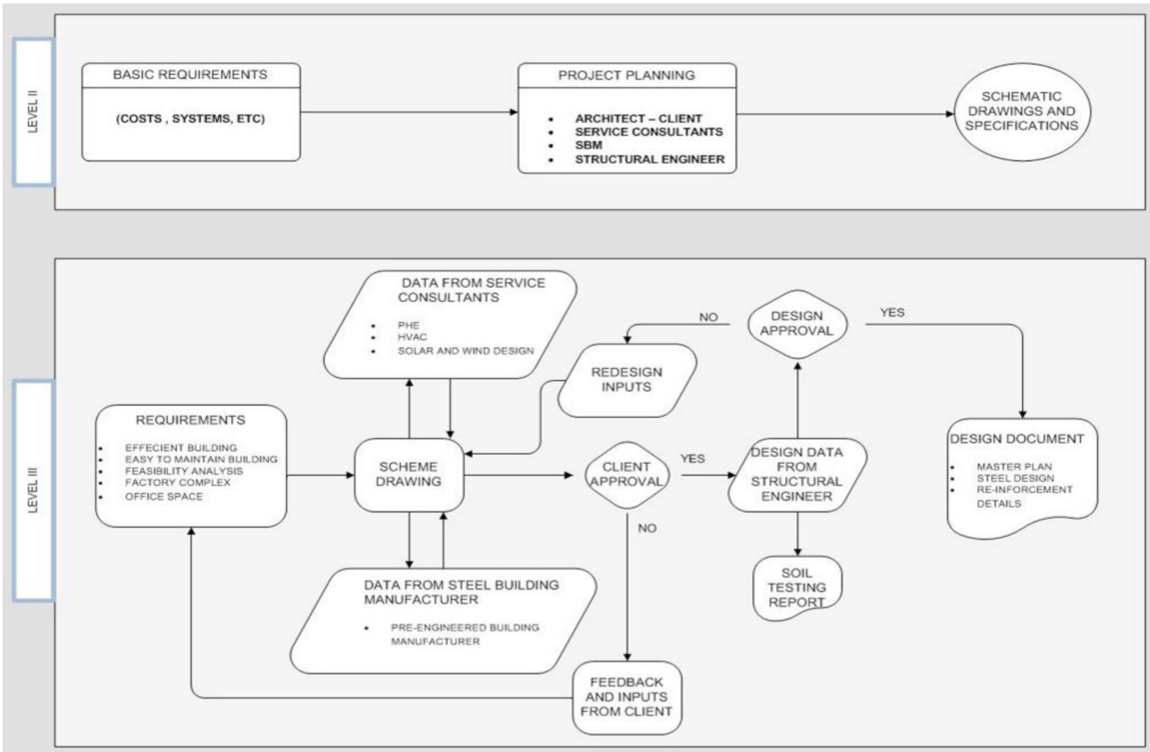
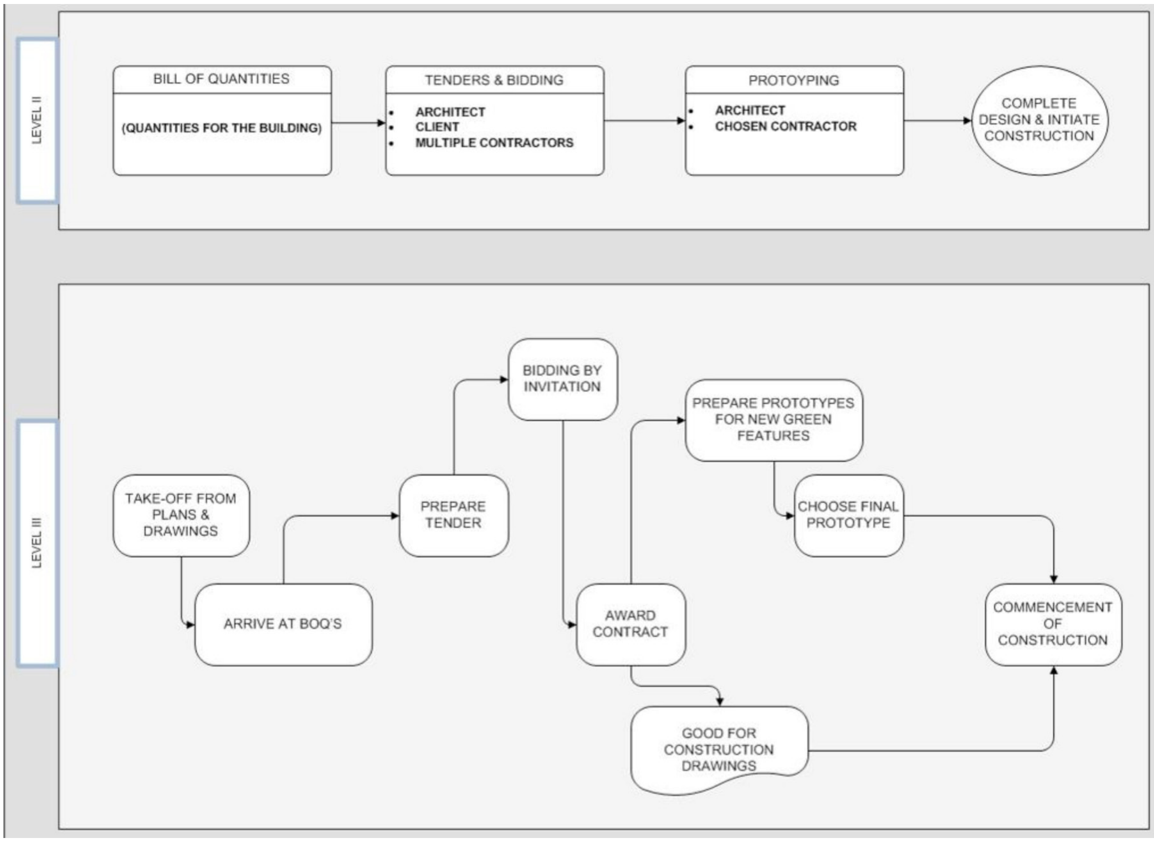


Figure 3 shows an example[2] of the Level 2 and Level 3 mapping[3]. The example is an expanded view of the "planning" phase from the Level 1 map. In the Level 2 map, which is shown in the top portion of Figure 3, the planning process has two activities and one output. The first activity, "Basic Requirements," examines the need for the project as stated by the owner. During this activity, the architect and the owner identify the type of building required and other guiding requirements, such as general sustainability goals for the project. The second activity "Project Planning" describes the stakeholders involved during the planning phase for the Soundarya building. The outputs from the planning process are the schematic drawings and specifications for the project.

The Level 3 mapping, which is shown in the bottom portion of Figure 3, provides additional planning process detail. The first activity for the Soundarya project was the owner's statement of project requirements: a factory and office complex which will "optimize economic output and minimize environmental damage." The owner also provided more specific requirements during this activity, such as "an efficient and easy to maintain building." Feasibility studies were used to evaluate these requirements. For example, one of the main requirements was that the owners would only consider sustainable features with a payback period of

[2]Level II and III maps were also prepared for the construction, post-construction, and post-occupancy phases of the Soundarya project. These maps are not included here, but are available from the authors on request.
[3]Process maps are read from left to right, following the arrows, which represent process flow. In the level 2 maps, rectangles represent activities and circles represent outputs. In the level 3 maps, rectangles represent processes, diamonds represent decisions, slanted rectangles represent inputs or outputs to a process, and the rectangles with a curved bottom line represent documents.

FIGURE 4. Level 2 and 3 map of the design phase for the Soundarya project.



less than 2 years. After the project requirements are clearly defined, the architect worked with various subconsultants for solar and wind energy; heating, ventilation and air conditioning; and public health engineering design. Simultaneously, the architect used input from the steel building manufacturer to develop a schematic design drawing for the building.

This draft schematic design drawing was then sent to the owner (Soundarya) for approval. Based on owner feedback, the architect worked to redesign the schematic drawing. After owner approval, this schematic drawing was sent to the structural engineer. The structural engineer considered the schematic drawing and the soil test reports to design the footings, columns, and reinforcements for the building. Then, the drawing and structural design were sent to the architect for approval. The final design document for this phase included the master plan of the project, the schematic drawings for the building, and the structural reinforcement details.

Process Attributes for the Soundarya Project

Based on the understanding of the Soundarya project that was gained by developing the level 2 and 3 maps, process attributes were identified that appeared to contribute to the Soundarya building's effective achievement of more sustainable performance. These attributes were initially identified by the researcher, using the process maps and interview data. Follow-up interviews with relevant project stakeholders were used to verify and gather additional information on these attributes. Attributes listed in the process maps and verified by project stakeholders are listed here.

- *Soundarya Decorators' knowledge of and early commitment to sustainability from their regular business practices.* This attribute was identified in the requirements activity in the Level 3 map for the planning phase. Soundarya possessed expertise in sustainability, developed over time in their regular business practices, which they brought to this building project. As a result, decisions from the first day of the Soundarya project kept the goal of sustainability in mind. This allowed the project team to take advantage of early opportunities for sustainability, such as optimizing building orientation, and contrasts with projects where the owner has less sustainability expertise and therefore more likely to see it as something to be added on at the end of the project instead of integrated throughout the process. In addition, the early commitment meant the design team did not need to use valuable design time convincing Soundarya of the merits of a more sustainable approach to building. Especially because Soundarya was the owner, their early commitment to sustainability helped set the tone for other stakeholders for the remainder of the project. Project teams with minimal sustainability experience can benefit from following the checklist approach offered by LEED[4] and other rating systems. For these project teams, an added benefit of LEED is that it encourages training and learning to provide a foundation for implementing sustainability on building projects.
- *Goal set for sustainability, as opposed to a certain level of LEED certification.* This attribute was identified by the value definition guiding the Soundarya project: "optimize economic output and minimize environmental damage." The value definition did not specify a certain level of LEED certification. This fostered a design approach which looked for the best sustainable solutions for the Soundarya project as opposed to misusing the LEED system by simply point-shopping for features needed for certification. Certification systems like LEED play a valuable role quantifying sustainability. Still, the results from the Soundarya case study show that some of the project's success was possible through design considerations, such as the curved roof shape, not covered explicitly in the LEED credits. This performance-focused approach was possible because of the sustainability expertise the project team brought to the Soundarya project. Project teams new to sustainable design may be better served by following LEED's more prescriptive approach.
- *Presentations to project stakeholders explaining sustainable features.* This attribute was identified in the conversation related to Soundarya's value definition. Powerpoint presentations on sustainable buildings and related technologies were used to help educate project participants.
- *Sustainable features aligned with business objectives.* This attribute was identified in the client approval in the Level 3 map of the planning phase. While committed to sustainability, Soundarya also had a clear process for evaluating the business case for sustainable features of the building. If proposed sustainable features cost more than the equivalent standard practice, these features had to demonstrate a payback period under 2 years, in which case Soundarya agreed to invest the first-cost premium. The length

[4]LEED, which stands for Leadership in Energy and Environmental Design, is the green building certification system of the U.S. Green Building Council.

of the payback period (public owners might allow a longer payback for example) is less important than the fact that this policy encouraged a systematic approach to selecting the most cost-effective sustainable design options. For instance, the Soundarya project used a light-colored roof with large overhangs to reduce solar heat gain and minimize cooling loads. Other approaches could have been used to minimize cooling loads, or solar photovoltaic panels could have been used to generate electricity to offset a similar amount of cooling loads. The light-colored roof satisfied Soundarya's business case and was selected because it met the 2-year payback requirement while contributing to the sustainability performance goal by reducing cooling loads, which reduces energy consumption and the associated climate change emissions.

- *Sustainable design expertise included on the project team.* This attribute was identified in the selection of design consultants in the Level 3 map of the design phase. Because sustainable building is a relatively new field in India, finding design consultants with expertise in this area can be challenging. Anand and Associates, the design consultants for the Soundarya project worked previously in a similar role on sustainable buildings in the United Kingdom. The experiences these consultants brought from their previous projects were applied to the Soundarya project.
- *Time invested in feasibility studies.* This attribute was identified in the feasibility analysis activity in the Level 3 map of the planning phase. For the Soundarya project, this analysis went beyond the typical feasibility analysis for a building project. The Soundarya feasibility analysis included additional studies on topography that were needed to evaluate the potential for, and eventually design, the water and wastewater management system that conserved water and improved sustainability performance of the building. Investing time in analyses like this helped identify opportunities to meet the sustainability performance goals and satisfy Soundarya's business case requirements.
- *Perform occupant feedback and independent audits for energy and water systems.* This attribute was identified in the Level 3 map for the post-occupancy phase. The Soundarya project emphasized ensuring their building would operate as designed, which is not always the case with "sustainable" buildings (Turner and Frankel 2008). After the Soundarya building was used for a couple of months, the design consultants gathered occupant feedback on the performance of the energy and water systems. Remedies were made to address negative feedback and ensure these systems were operating as designed. After addressing occupant feedback, the energy and water systems were also audited by a 3rd party to ensure unbiased measurement of their performance.

Comparison of Process Attributes for Soundarya and the Toyota South Campus Building

For comparison to the Soundarya project, the Toyota south campus building was selected because of the available peer-reviewed study of its delivery process using a process mapping approach (Lapinski et al. 2006). The study of the Toyota south campus building (Lapinski et al. 2006) revealed process attributes contributing to that project's cost-effective achievement of sustainable performance goals. This study was among the first to link process attributes to sustainability outcomes and, therefore, to suggest methods to reduce sustainable building costs without compromising performance.

Toyota's south campus building is located in Torrance, California. Specific sustainable elements of the Toyota project include: reduced use of potable water by using reclaimed water for irrigation, toilets, and absorption chillers; reduced energy consumption for heating and cooling by use of a mechanical system including absorption chillers and boilers; reduced consumption of raw materials by using over 50% of materials with recycled content; and reduced waste sent to landfills by recycling over 95% of construction waste.

Comparing process attributes identified for the Soundarya project to those identified for the Toyota project provides another data point for determining process attributes which contribute to successful sustainable building projects. In addition, this comparison can help answer whether there are fundamental differences between the countries that might prevent leapfrogging of sustainable delivery process attributes.

The study of the Toyota project identified eight process attributes. These process attributes are described in the left column of Table 3. Six of the seven process attributes for the Soundarya project, which were described previously and listed in the center column of Table 3, are similar to those identified for the Toyota project. For each of these six matching attributes, a summary is provided in the right column of Table 3. Matching attributes include: demonstrate an early

TABLE 3. Matching process attributes for the Soundarya and Toyota projects.

Process attribute (Toyota)	Related process attribute (Soundarya)	Attribute summary
Toyota's support for identification of sustainable opportunities from the beginning of the project	Soundarya Decorators' knowledge of and commitment to sustainability from their regular business practices	Highlight an early owner commitment to sustainability
Sustainable project opportunities identified regardless of LEED certification efforts	Goal set for sustainability, not a specific level of LEED certification (e.g. "optimize economic output and minimizes environmental damage")	Outline goals related to sustainability, not a specific level of certification
Formal statement of project sustainability efforts; Learning from and sharing project successes and challenges	Presentations to project stakeholders explaining sustainable features	Require continuous education of project stakeholders on sustainability
High performance sustainable facility goals aligned with the overall project business need	Sustainable features aligned with business objectives (e.g. 2-year payback)	Align sustainable features with business objectives
Team members selected from a preferred network of Business Partners	Sustainable design expertise included on the project team	Name project team members with sustainability expertise
Multiple solutions explored prior to picking a direction	Time invested in feasibility studies (e.g. topography studies to design storm water management system)	Make time during design to consider alternative sustainable solutions
Cross functional input from all disciplines throughout delivery	No related process identified	
Business Partners challenged to continuously improve	No related process identified	
No related process identified	Occupant feedback and independent audits for the energy and water systems	

commitment to sustainability by the owner; set goals related to sustainability, not a specific level of certification; continuously educate project stakeholders on sustainability; align sustainable features with business objectives; encourage project team buy-in to sustainability goals; and invest design time to consider alternative sustainable solutions.

CONCLUSIONS

The results of this research suggest that sustainable building delivery process attributes which are effective in the U.S. will also be effective in India and vice versa. Despite differences between the U.S. and India, the process maps showed that the delivery of the Soundarya project in India was similar to the delivery of the Toyota project in the U.S. Because of the similar processes and process attributes, each country could potentially leapfrog directly to best practices for sustainable project process attributes used in the other. These process attributes can help address critical barriers to more widespread adoption of sustainable building in the U.S. in India. For example, one barrier is the unorganized nature of the construction industry in India (Potbhare et al. 2009), and adoption of these process attributes would provide some organization to help combat this barrier.

Based on the findings of this research, several process attributes, common to the Soundarya and Toyota projects could be used as a starting point for that leapfrogging.

- Highlight an early commitment to sustainability by the owner: The owners for both projects brought a commitment to sustainability, developed over time in their regular business practices, to their building project. They shared this commitment with the project team, which helped ensure decisions from the first day of the project kept the goal of sustainability in mind.
- Outline goals related to sustainability, not a specific level of certification: Both projects took a performance-focused approach, looking for the best sustainable solutions for their unique project as opposed to misusing a rating system by simply point-shopping for features needed for certification.
- Require continuous education of project stakeholders on sustainability: Both projects incorporated ongoing sustainability training as part of the requirements for project stakeholders. Knowledge sharing was encouraged among project stakeholders.
- Make time during design to consider alternative sustainable solutions: Both projects were able to invest design time to identify and evaluate these sustainable solutions. A rushed design process might have missed these opportunities.
- Align sustainable features with business objectives: Both projects had a clear process for evaluating the business case for sustainable features of the building. This helped encourage a systematic approach to selecting the most cost-effective sustainable design options.
- When possible, name project team members with sustainability expertise: Both projects did this, which helped encourage project team buy-in to sustainability goals.

When considering these attributes and drawing other conclusions based on this research, we must remember that it is based on study of a single project in India and a single project in the U.S. In-depth process mapping studies like this are time-consuming, but necessary to generate the rich insights required to identify key attributes. Additional research on other successful projects that have achieved high levels of sustainability performance would be very useful to compare with the results of this study.

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