Lean Processes for Sustainable Project Delivery

Anthony R. Lapinski[1]; Michael J. Horman[2]; and David R. Riley[3]

Abstract: Facility owners and project teams often struggle to engage "green" or "sustainable" requirements on building projects and can incur additional project costs as a result. Although "investments" in high performance building features can be paid back through operational savings, the project delivery methods currently adopted by most teams are laden with process waste. Lean production principles have been proven to reduce waste and improve process performance in highly complex development and production environments. Adopting these lean principles, this paper reports a study that identified the presence of value and waste in a sustainable building project. Through an empirical investigation of the Real Estate and Facilities Division of Toyota Motor Sales, Toyota's capital facility delivery process was mapped to identify both the steps in project delivery critical for success (value) and those that are waste. The investigation focused on the South Campus Facility, which received U.S. Green Building Council's Leadership in Energy and Environmental Design Gold certification at a project cost equivalent to a conventional facility. Through post hoc process-based analysis, insight about what added value and waste in sustainable project delivery at Toyota was obtained. The results also identify further improvement opportunities to Toyota's delivery process. For corporate facility owners and the Architecture Engineering Construction industry, the results unearth insights about how to successfully and economically deliver sustainable facilities.

DOI: 10.1061/(ASCE)0733-9364(2006)132:10(1083)

CE Database subject headings: Delivery; Sustainable development; Construction industry.

Introduction

"Green" or sustainable buildings offer numerous benefits including energy efficiency, improved indoor environment quality, increased health and occupant productivity, and the minimization of resource usage during the construction and operation of the building. Consequently, these buildings achieve superior long-term performance making them attractive investments for facility owners and developers in both the public and commercial sectors.

However, to achieve their performance benefits, additional requirements are often needed in the delivery processes for sustainable buildings. For example, sustainable building projects require intense interdisciplinary collaboration, highly complex design analysis, and careful material and system selection, particularly early in the project delivery process (Riley et al. 2004). Additionally, locally manufactured, often untraditional, and higher priced materials can be required for construction; and if certification under the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) is sought, extensive documentation adds time and cost to the project (Pulaski et al. 2003).

To account for the additional requirements posed by sustainable buildings, an up-front or first cost premium is commonly associated with this building type. This up-front cost is used to purchase better quality building components like HVAC systems and superinsulated building envelopes. This "investment" can achieve significant operational savings that extend over the life of the building. However, the current project processes used to deliver sustainable buildings are often laden with wasteful rework, delays, changes, and overproduction (Horman et al. 2004). Project delivery processes are the processes used to get owner needs to a constructed facility, and include programming, procurement, design, construction, and turnover. We suppose that part of the reason for high process waste is that owners and project teams have a limited understanding of which processes are the important ones for sustainable project delivery. Further, the intermediate deliverables, activities, and outcomes of current delivery processes are best suited for conventional building types and are often unresponsive to the needs of sustainable building projects (Lapinski et al. 2005). For instance, traditional delivery processes make little explicit mention of important sustainable activities such as energy modeling. Critically, the increased first cost associated with sustainable buildings is a major barrier for owners to pursuing sustainable building objectives.

A number of exemplary sustainable buildings, however, are emerging to suggest that the requirements of sustainable projects need not lead to increased project costs. Facility owners like Toyota Motor Sales have been able to deliver LEED Gold-certified facilities without a first cost premium (Pristin 2003). This is a notable accomplishment compared to an industry average 5–10% cost premium often needed to deliver LEED certified buildings (Smith 2003).

Teams experienced in sustainable building development are revealing that process efficiencies are key to the low-cost delivery of sustainable buildings. This is a critical emerging development

[1]Formerly, Graduate Student, Dept. of Architectural Engineering, Penn State Univ., 203 Engineering Unit A, University Park, PA 16802.

[2]Associate Professor of Architectural Engineering, Penn State Univ., 211 Engineering Unit A, University Park, PA 16802. E-mail: mjhorman@engr.psu.edu

[3]Associate Professor of Architectural Engineering, Penn State Univ., 220 Engineering Unit A, University Park, PA 16802. E-mail: driley@engr.psu.edu

Note. Discussion open until March 1, 2007. Separate discussions must be submitted for individual papers. To extend the closing date by one month, a written request must be filed with the ASCE Managing Editor. The manuscript for this paper was submitted for review and possible publication on July 25, 2005; approved on March 20, 2006. This paper is part of the ***Journal of Construction Engineering and Management***, Vol. 132, No. 10, October 1, 2006. ©ASCE, ISSN 0733-9364/2006/10-1083–1091/$25.00.

in our industry. As the Architecture Engineering Construction (AEC) industry becomes more adept at the technologies for sustainable buildings, it must also understand and overcome the process issues of these buildings. This industry needs to identify which processes enable sustainable goals to be achieved most efficiently. Although our community has studied lean project delivery and sustainable building objectives for some time, there has been little scientifically supported research that combines these two domains together.

Armed with the theory that process waste affects both sustainable outcomes and the business case for sustainability, this paper analyzes the delivery process of Toyota's capital facilities program. Advances in manufacturing processes, especially those in lean production, demonstrate the power of harnessing production science to improve product quality (increasing value) and at the same time dramatically speeding production and reducing costs. Using principles of lean production, the Toyota capital facilities process is systematically modeled and analyzed to capture and understand the key process attributes. This will provide an understandable breakdown of which processes add value and help to define what process improvements in sustainable building projects look like, thus helping the AEC industry to achieve low-cost sustainable buildings.

Objective

The purpose of this paper is to evaluate, using the scientific approach, the life cycle of Toyota's capital facility delivery process to empirically identify the critical activities and capabilities that led to Toyota's South Campus project success. This will involve a post hoc process-based analysis to identify where value and waste were generated in Toyota's delivery system.

Background

Sustainable Project Delivery: Toyota and U.S. General Services Administration (GSA)

Toyota Real Estate and Facilities (RE&F) is responsible for the development, design, construction, operation, and maintenance of all Toyota Motor Sales in North America (TMS) corporate facilities. TMS are responsible for all postmanufacturing operations at Toyota Motor Company. The design and construction of Toyota's manufacturing facilities throughout the world are the responsibility of Toyota in Japan, not TMS. Thus, project types undertaken by RE&F include corporate offices, parts and vehicle distribution centers, logistical support facilities, training facilities, financial facilities, executive housing, and airport hangars. Their work involved 80–100 projects at a total yearly budget of $100 million. Vehicle distribution centers, parts distribution centers, and technical training facilities comprise the bulk of their work.

Toyota's first LEED certified building was the South Campus facility located in Torrance, Calif. (see Fig. 1). This three-story office building of approximately 59,500 m^2 (640,000 ft^2) received Gold certification. Some of the noteworthy features of the facility include:

- Reclaimed water used for irrigation, toilets, and absorption chillers, eliminating the use of almost all potable water;
- Equipment in heating, ventilation, air conditioning, and refrigeration does not require ozone depleting chlorofluorocarbon (CFC)-based refrigerants by use of a mechanical system including absorption chillers and boilers;
- Energy performance exceeds California Title 24 State Energy Code by over 42% and American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) standards by 60%. The roof holds the largest photovoltaic array in California providing 20% of the building's total energy [2,232,000 MJ (620,000 kWh annually)];
- Over 50% (by value) of materials including all system furniture have incorporated recycled content material to reduce the impacts from extracting new materials; and,
- 97% of construction waste was recycled to avoid landfills and recyclable materials directed back to the manufacturing process. This included using tilt-up casting beds as stone steppers in the garden areas.

Fig. 1. Toyota Motor Sales' South Campus facility received Gold LEED certification

At $87 million, this was an unusually large project for Toyota. However, a project cost of $6/m^2 ($63/ft^2) lies in the range of $5 to $7/m^2 ($54 to $76/ft^2) for most of southern California office parks indicating that Toyota was able to obtain an environmental building of very high standard at little or no additional cost over a conventional building (Pristin 2003). A study by the GSA (2004) of the cost of pursuing LEED on their facilities showed that a modest budget allocation of 2.5% was sufficient for them to achieve Silver certification. The report concluded that this cost was well within the regular estimating "noise" of their projects, i.e., the typical range of cost variations they experience due to estimating and change orders. Clearly, owners such as Toyota and GSA have effective teams and processes for delivering their sustainable facilities that should be closely studied so our industry can learn how to efficiently deliver their green facilities.

Lean Production: Focus on Process

Process-based theories and modeling strategies can help to understand the delivery attributes of sustainable buildings. The Toyota Production System (TPS) and its lean principles provide insight about the way a process is recognized, documented, and assessed for improvement. The TPS utilizes a process-oriented approach to maximize value generation for the customer by stripping away process waste and enhancing production flow. Identifying instances of value and waste first begins by defining the customer base. The customer base of the TPS is the vehicle owner. Value is generated by meeting the needs of owners in terms of price, color, options, availability, etc. (Bremner 2003). Conversely, waste is any activity or process that adds no value to the customer.

The lean analysis of production flow requires documentation or mapping of the process (Liker 2004). This process map emphasizes a total process perspective and provides prerequisite understanding for analyzing processes for value and waste. At Toyota, impressive performance has resulted from the process maps, corresponding analyses, and adopted value-enhancing and waste-eliminating improvements. Manufacturing lead times have fallen by 48%, productivity has increased by 53%, quality has improved by 65%, and product development is completed with 45% fewer engineering hours at a pace 24% faster than any of Toyota's U.S. counterparts (Womack et al. 1990). Applying the lean principles of the TPS to Toyota's capital facility delivery process offers important procedural guidance to capture and understand the enablers of their success as well as opportunities to improve their process further.

Inspired by Koskela's (1992) important study of production theories in construction, this industry has embraced lean principles for nearly 15 years. Most research and implementation has focused on construction processes, especially addressing the waste-inducing effects of poor planning (e.g., Ballard and Howell 1998). Some work has extended to the design process, and even lean project delivery (Ballard and Zabelle 2000; Ballard 2000); although, the results have not yet matched those achieved by Toyota manufacturing. The lean construction community has performed a number of modeling and simulation studies of project and supply chain processes (e.g., Tommelein and Li 1999; Tommelein and Weissenberger 1999; Arbula and Tommelein 2002), although these studies have been confined to partial segments of the delivery process and do not necessarily emphasize understanding where value is generated or lost. The synergistic and cost-saving link between process waste reduction in the TPS and reduced resource use in sustainable development has been made by others, but is only now being extensively pursued (Huovila and Koskela 1998; Hawken et al. 1999; Horman et al. 2004).

Research Methodology

Mapping the Delivery Process: Data Collection

To capture and evaluate Toyota's sustainable building delivery process, a modeling approach was developed to map the entire capital delivery process, i.e., programming through design, procurement, construction, handover, and operation. Extensive review of lean mapping techniques and current building process models revealed the importance of evaluating value and waste in process analysis (Rother and Shook 2000; Rother and Harris 2002; Hines and Taylor 2000; Liker 2004). The features of the adopted modeling approach draw on the Integrated Building Process Model developed at Penn State (Sanvido 1990). This model, based upon the IDEF0 modeling language, uses an input-activity-output relationship to identify the key steps required to provide a facility to the end user. The power of this model is in the systematic rigor at which the entire process of building delivery is described, and the ability to adapt it to map process value and waste (Horman et al. 2006).

The first step in the adopted methodology was to understand value in terms of the process customer. As for most facilities, the building end user is the final customer at Toyota RE&F. The end user needs include space, functionality, aesthetics, proper Toyota image, and price. A similar set of needs would exist for other end users. Value is generated when these needs are fulfilled. However, when a Toyota facility is built to be sustainable, the environment is introduced as an additional customer (Horman et al. 2004). The environment's needs include sustainable development principles such as minimal building impact, maximum building system efficiency, and a healthy and productive occupant environment. Again, value is generated by fulfilling this specific needs set. Fig. 2 shows how the needs of the end user and the environment are woven together to provide a framework for identifying and assessing how value is generated for sustainable facilities at Toyota.

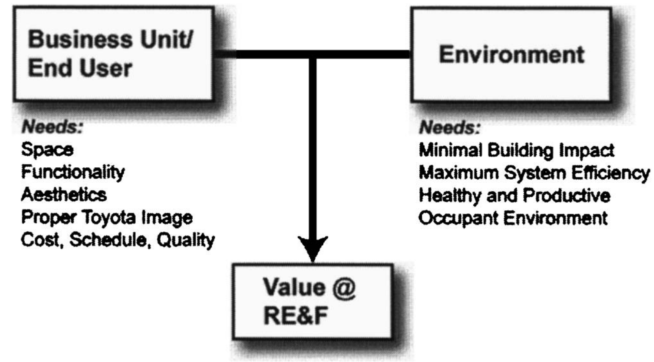

Fig. 2. Customer needs of the end user and the environment define value at Toyota

With a definition of value established, detailed process maps were then developed. These maps provide a pictorial representation at increasing levels of detail of the steps Toyota uses to deliver their capital facilities. Penn State researchers embedded themselves in the Toyota RE&F organization for five months meeting daily with the various departments to document their processes. Microsoft Visio was used to manage the extensive data obtained. Maps at three levels of detail were developed. The first level shows overall phases indicating where each department becomes involved in a project. The second layer documents resource (people) and information flows. The third, and most detailed layer, shows the functions performed, inputs needed, and outputs produced. These maps capture the entire development process providing the foundation to assess the value generating and waste laden properties of each process activity. To ensure their accuracy, the maps were verified by each department and the entire organization.

Data Analysis

Analysis of the process maps was performed with three objectives in mind: (1) Understand where value and waste are generated in the delivery process; (2) understand the important features that are responsible for the successful delivery of Toyota's sustainable buildings; and (3) identify opportunities for continuous improvement of the Toyota RE&F delivery process.

During the value assessment, each activity was scrutinized to evaluate whether it met the needs of either the end user or the environment. If RE&F could attribute no value in these terms to the activity, it was designated a waste. In some instances, an activity was found to be wasteful, but essential to achieve a value added outcome. In these cases, the activity was noted to be nonvalue adding. Lean principles state that nonvalue-adding activities are type two waste and should be the focus of long-term improve-

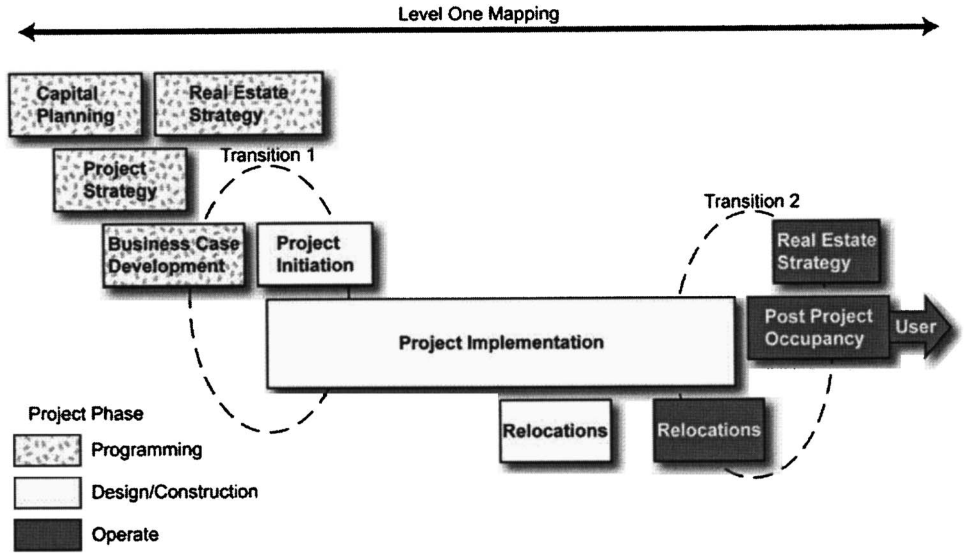

Fig. 3. Level 1 of the Toyota capital delivery process

ment efforts (Liker 2004). For the purpose of this research study, the aim of the value assessment was to identify all instances of process value and waste (including nonvalue adding) in relation to Toyota achieving sustainable goals. In the future, a more detailed distinction of type one and type two waste would be a useful extension of this research.

Having assessed where value and waste were generated in the delivery process, activities were then examined for their contribution to the sustainable goals for the project. The purpose was to provide an understandable breakdown of value-added activities that contribute to sustainable objectives during project delivery. Finally, the analysis focused on identifying opportunities for delivery process improvement. The purpose of this step was to reveal what process improvements in building project delivery look like.

Model Validation

To help validate the capability of the model to capture and reflect process attributes in the Toyota capital facilities program, a completed project was mapped and compared against the generic delivery process map. It was hypothesized that if the generic process map could capture the essence of a real project then this helped validate the diagnostic functionality of the mapping protocol. The project evaluated was the completed Lexus H/Q renovation. The project manager used our modeling protocol to document the process map for this project. This map documented a similar number of inputs, activities, and process outputs to the generic process map, suggesting the mapping protocol was comprehensive at documenting a real project. More importantly, however, the map comparison insightfully documented many of the major challenges on this project. The Lexus H/Q project was suspended for eight months until the 2003 fiscal year, resulting in supplementary rework in programming, and process dysfunction due to missing the Project Initiation phase of Toyota's project delivery process. The map linked very clearly the downstream effects of these issues during design and construction. This was noteworthy for the post mortem of the project because it dispelled previously misunderstood and underdevelopment reasons for the suboptimal delivery performance that initially had included a faulty project team and mismanagement by the project manager.

Results

Process Maps

Fig. 3 shows the first level of Toyota's capital delivery process. During the programming phases, projects are solicited by Real Estate and Facilities from various Toyota business units (end users). Initially, these are general requirements and requests that RE&F uses to create a capital budget for the coming year. Once in the capital budget, the strategic needs of the business unit are assessed, project scope is planned, and a business case is devised for each project. Having received corporate sign off at this point, the project proceeds through Transition 1, which consists of a series of Project Initiation meetings to select a project team (architect, consultants, etc.) and to hand the project off to that team for Project Implementation (design and construction). There is nothing uniquely integrated about this phase of the delivery process which proceeds in a largely sequential manner. Transition 2 represents facility turnover at project completion. Relocations are a particular RE&F workgroup responsible for moving the business unit into their facility. In an effort to ease this transition, this group has become involved earlier in project implementation. Operations and Real Estate inherit the facility and are responsible for facility use and realty-related issues (e.g., leases, etc.).

Fig. 4 shows a sample of the second and third levels of the process map. These levels reveal progressively more detailed steps of the delivery process. The example shown is that of Business Case Development. The second level map (top of Fig. 4) shows the basic steps of the phase, indicating who is the owner of the step (in dark gray) and who will be involved (in medium gray). The inputs and outputs at this level concern the critical information flow through the steps. Ownership, participation, and information requirements were not previously well defined in the RE&F organization and often led to delays, rework, and other waste in their process.

The third level map (bottom of Fig. 4) shows the detailed inputs, function and outputs needed in each step of the process. These are the same as the second level, but in more detail. Rules for modeling were used to provide coherency to the map. For example, for a function to be included on the map, it had to possess an input, either separately defined or the output of a pre-

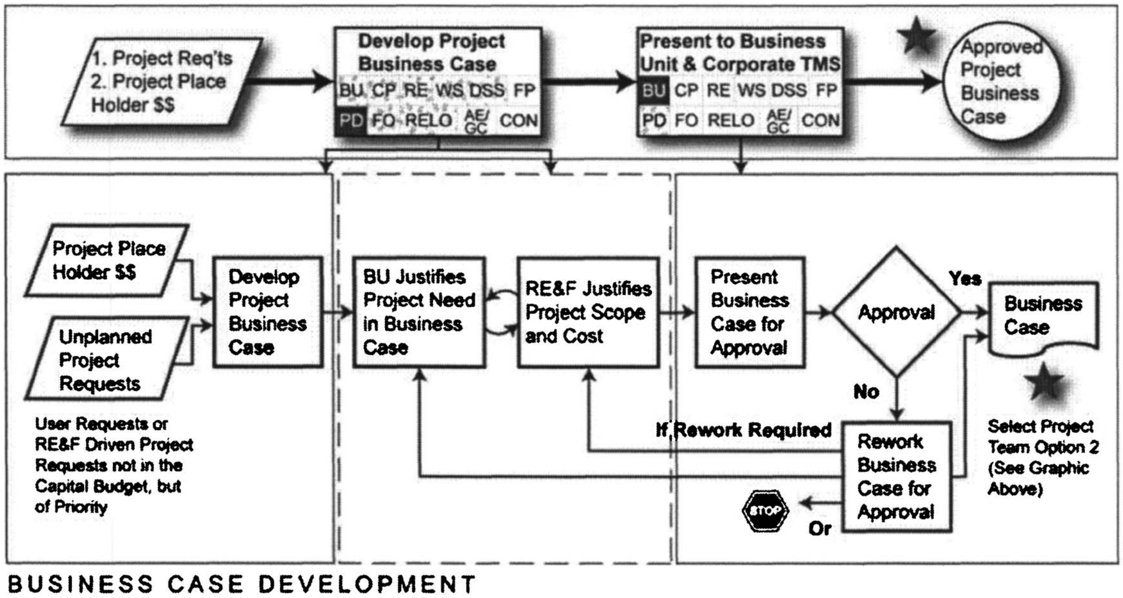

Fig. 4. Sample portion of Levels (top) 2 and (bottom) 3 of the Toyota capital delivery process

viously completed step, and an output that was used at another step in the delivery process. At this level of detail, the value and waste attributes of activities could be analyzed.

Process Performance Analysis

At the greatest level of detail, the process map identified a total of 23 inputs, 124 total activities, and 36 total process outputs. Of those 124 activities, the value assessment of the process map revealed 40 of those activities added value whereas 84 activities were wasteful, i.e., the current Toyota delivery process generates 32% value added for their customer base (Table 1). By way of comparison, Horman and Kenley (2005) in a large study demonstrated that projects average 50% wasted activities, although this analysis was confined to construction processes not taking account of other project delivery phases, like design. Manufacturing studies have empirically shown waste to be as high as 85–99% (Stalk and Hout 1989; Hines and Taylor 2000; Liker 2004). The exact proportion of value added to waste is likely to vary depending on the underlying complexity of the process and whether activities are measured in terms of schedule or cost. What is most useful about the value assessment of the process map is that Toyota's delivery process is not particularly efficient. In fact, Toyota has an opportunity to eliminate 68% of their project delivery activity to streamline their sustainable building delivery process.

Table 1. Quantitative Analysis of Value and Waste Steps in Toyota's Capital Delivery Process

Function	Value added activity (% of total activity)		Waste and nonvalue added activity (% of total activity)	
	Baseline	Lexus	Baseline	Lexus
Capital planning	29	27	71	73
Project strategy	43	46	57	54
Real estate strategy	33	N/A	67	N/A
Business case development	40	33	60	67
Project initiation	25	0	75	100
Project implementation	30	28	70	72
Relocations	29	29	71	71
Postproject occupancy	38	38	68	68
Average over the total delivery process	32	27	68	73

It is also interesting to evaluate where Toyota adds most value and where it is most wasteful. A notable capability of the map is that it is possible to conduct this evaluation of the total process (not just phases or parts). Table 1 reveals that the processes where the greatest value was added were Project Strategy, Business Case Development, and Postproject Occupancy. These processes are not surprisingly high at generating value since they involve quite high levels of interaction with the end user (business unit). What is perhaps surprising is that Project Initiation and Project Implementation (i.e., design and construction) appear to add very low levels of value. Examples of the major waste found in design and construction included mismatched procurement of design and construction services so that excessive delays and rework occurred to form a coherent team. An excessively large number of small subcontractors were procured as a way of controlling costs at procurement, but at the expense of bidding delay, excessive rework, and reduced economies of scale and poor integration. These processes are the core of what the AEC industry does, i.e., design and construct buildings. These results suggest that this industry might not be very efficient in adding value.

The process analysis also revealed critical wastes in Toyota's capital facilities program. Table 2 outlines the significant delivery process wastes that were identified in this study. The total perspective and process orientation of the maps were critical to recognizing and understanding these wastes. Notably, the transitions identified in Fig. 1 were major bottlenecks in process flow for project delivery. As an example, the first process waste identified in Table 2 was largely the result of a small number of senior Toyota management overburdened with presenting the business case to corporate executives, and then initiating the project. Often projects approved in the Capital Planning budget were held in

Table 2. Key Wastes as Captured by the Process Map

Process waste	Solutions developed to eliminate process waste
Inconsistent flow through delivery process	**Level process flow:** Achieved through the identification, elimination, and resequencing of overburdening activities. This proved to reduce bottlenecking and improve process flow
Complex activity and process sequences	**Elimination of excessive project parameters:** Including instances of overproduction, redundancy, excessive checks/signoffs, and activities that did not generate outputs
Lack of process transparency	**Project delivery plan:** A simplified process map that clearly communicates the delivery process. This tool improved process transparency and helped to better manage customer expectations
Segregated department structure	**Integrate department workgroups:** Emphasis was placed on increased involvement from O&M early in the delivery process, i.e., during project programming through design. This proved to ease downstream bottlenecking and help process flow
Inconsistent feedback and continuous improvement mechanisms	**Postproject evaluation (PPE):** A revised PPE was developed and implemented. This tool enabled project performance and improvement opportunities to be consistently captured and evaluated

limbo for weeks before they transitioned to Business Case Development because of this overburdening. In other examples, some of the procedures adopted by Toyota reflected institutionalized waste, especially activities that were performed because that was the "Toyota approach." An example of this is the three Project Initiation meetings performed. Although these had always been done, they could be combined to one or two meetings and reduce waste.

Assessment of Toyota's Sustainable Building Delivery Process

Activities were then assessed for their contribution to the delivery of Toyota's sustainable buildings. The process map was instrumental in recognizing the environmental value of Toyota's capital facility program as many features were so embedded in the Toyota process that they were difficult to identify through other analysis techniques. One example of this is Toyota's use of the business case to drive the achievement of sustainable goals. The established value criteria acted as a lens to assess how specific process activities documented by the map fulfilled the needs of the environment. Table 3 identifies the vital steps throughout the life cycle of Toyota's delivery process and explains their value-added (i.e., lean) contribution.

The lean elements of Table 3 can be distilled into five core value-added processes that contribute to sustainable objectives during project delivery. The hallmarks of Toyota's success at sustainable building delivery include the following.

1. **Early evaluation and adoption of environmental considerations:** Sustainable objectives are evaluated and adopted very early in the Toyota delivery process, typically during project programming. This enables a clear understanding of sustainable objectives and generates upper management support.
2. **Business case imperatives:** Early evaluation and adoption of sustainable objectives allows project budgets to be aligned with environmental project goals. This significantly enhances the business case for sustainability as sustainable objectives are not "tacked onto the project" but woven into the project. Savings elsewhere in the project can be used to offset these increases. Equipment costs can be justified through life cycle and operational savings.
3. **Sustainable compatibility:** Sustainable building features are aligned to site conditions and parameters during project programming. In addition, sustainable building features that are included in the project scope must be conducive to the operational purpose of the building. For example, photovoltaic cells made good business and sustainable sense on the South Campus project in southern California. Yet, use of this clean energy source was not suited to the climate of the Oregon-based port of Portland project.
4. **Early selection of team members with sustainable experience:** Teaming is a critical part of sustainable building delivery. At Toyota, project teams are formed early, and include specialty contractors and design teams with sustainable project experience. Bringing these disciplines to the table early in the delivery process engages critical process integration and allows system and environmental knowledge to be tapped as design begins.
5. **Alignment of team member goals and project goals:** In addition to selecting the project team early, Toyota spends time before the project commences to clearly define success for the project. Team members share their needs for project success and alignment is sought. This process provides a clear benchmark for direction throughout the project and for performance assessment at completion.

These processes are employed regardless of whether LEED certification is being sought for a building or not. Seamlessly weaving the activities into Toyota's delivery process allows sustainable outcomes to be realized at little or no extra cost.

Improvement Ideas and Filter

The delivery process map has been instrumental in analyzing Toyota's success at sustainable building delivery, but has played an equally important role in revealing and focusing process improvement opportunities. Critical to the success of green facility delivery is to constantly challenge current levels of performance to continuously improve. Advances made by experienced teams in design and delivery efficiencies are being reinvested in sustainable facilities to offset the costs of more expensive, but efficient building systems. With 68% waste, Toyota's delivery process is not particularly "lean" and represents a significant opportunity to achieve efficiencies to reinvest in the sustainability of their facilities. The importance of *kaizen* or continuous improvement to Toyota corporate culture has recently been discovered to be at the heart of the TPS (Spear and Bowen 1999). Workers in the TPS have time deliberately carved out of their schedules to evaluate and experimentally test each process and activity in order to refine current practices before devising a targeted plan for improvement (Spear and Bowen 1999; Ohno 1988; Shingo and Dillon 1989).

Drawing on core lean theory that uses the scientific method to test and focus improvement ideas (Spear and Bowen 1999; Spear 2004), an Improvement Ideas Filter was developed for Toyota RE&F to capture and evaluate ideas. Aligned with corporate RE&F business objectives, lean principles of continuous improvement, and environmental goals, the filter classifies improvement ideas and then assesses each against a series of tests. Table 4 shows the filter, a number of improvement ideas, and the results of their evaluation. Five categories of tests were used to analyze

Table 3. "Lean" Element of Toyota's Sustainable Building Delivery Process

Strategy	Steps taken to execute strategy	Overall value added
Programming		
Identify unique environmental opportunities	Understand the project needed, e.g., renovation, new construction, lease. Evaluate site, e.g., location, climate, urban/rural. Assess building type, e.g., distribution center, office, port. Analyze client culture, e.g., progressive, concern for environmental issues	Ensures that all environmental opportunities are identified and explored
Determine likely LEED certification	Determine if LEED is appropriate. Does budget allow for it? Understand culture surrounding project, e.g., users, government, and marketing opportunities	Early decision whether to seek LEED certification
Align sustainable features with project budgets	Understand first costs verses life cycle cost. Assess and understand any potential budget impacts. Calculate long-term operational savings	Business case for sustainability made
Select project team with sustainable experience	Require all RFP respondents to discuss relevant experience with sustainable facility delivery and how they will help RE&F achieve environmental goals	Demonstrates ability to achieve sustainable objectives
Design/Construct		
Generate ecostatement	Develop a 1–2 page summary of the environmental initiatives regarding the project. Determine time and place for ecocharette. Distribute ecostatement	Communicates sustainable opportunities and objectives
Conduct design ecocharette	Develop environment project features based on identified opportunities. Establish understanding of goals throughout project. Seek additional information if necessary. Identify and take advantage of unique project features	Develops sustainable objectives that align with overall project goals
Revise ecostatement	Update ecostatement based on charette results. Review and realign with project goals if necessary; assess impact on business case	Finalizes project sustainable objective
Monitor on site sustainable programs	Review goals before and during construction. Educate team. Visit site to ensure proper adherence to sustainable initiatives	Ensures sustainable goals are achieved on site
Operate		
Educate maintenance staff and occupants	Inform occupants and operation/maintenance about sustainable building features and corresponding maintenance requirements	Makes certain sustainable building features are not compromised
Monitor operational performance	Assess and optimize building system performance to assure sustainable objectives are continually met	Ensures ongoing building systems performance

an idea: (1) Promotion of RE&F mission; (2) conformity to the project business case; (3) adherence to Toyota environmental policies; (4) elevation of facility sustainability; and (5) capitalizing on Toyota corporate culture. The tests in each category assess specific attributes of the idea, e.g., the likely effect on budget or schedule (Lapinski 2005). The results column is a simple pass rate (e.g., for the first idea, 21 of 23 tests passed). Based on these results, the ideas are ranked to help prioritize them. The intent of the filter is to objectively and systematically focus employee attention on the ideas that will generate the greatest value to the organization.

To test the filter, the two top ideas that passed through the filter were implemented and their process impact was assessed. The Postproject Evaluation was revamped to shorten the feedback loop to the project team by executing one additional evaluation at the end of design. Having implemented the new PPE process on three projects, follow-up surveys were performed that showed that the project teams found the revised approach very useful for recognizing deficiencies and enabling them the opportunity to make corrections before project completion. This is not possible with the original PPE at project completion. The second idea was to increase project transparency by developing a project development plan to describe the project delivery process to the business unit (end user). This document shows key project milestones, explains their purpose, highlights the environmental enhancements occurring, and identifies the points of end user participation and key decisions needed. Employed on two projects to help end user participation, end users were surveyed and indicated a strong preference for this tool to help them understand the process and make timely decisions so as not to unduly delay the projects. These results are documented in Lapinski (2005).

Conclusions

Many capital facility owners and building project teams make mistakes early due to inexperience on the unique and challenging requirements of green buildings. On Toyota's South Campus project, a LEED Gold certified building was procured at no additional cost with respect to conventional facilities of similar size and scope. To understand Toyota's success, the lean principles of

Table 4. Continuous Improvement Filter

Improvement idea (idea classification: 1–flow, 2—complexity, 3–transparency, 4–Integration, 5–continuous improvement mechanism)		Category 1				Category 2				Category 3				Category 4				Category 5							Results		
		Test				Test				Test				Test				Test							Total score rank		
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	5	6	7	Yes		
5	Revise the Postproject evaluation process	X	X	X	X		X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	21	91%	1
3	Identify project driver early in the process	X	X	X	X	X	X	X	X					X	X	X		X	X	X	X		X		16	70%	11 tied
3	Better manage project expectations	X	X	X	X		X	X	X	X	X		X	X	X		X	X		X	X	X	X	X	19	83%	2
1	Increase interaction between design team and contractor throughout project process		X	X	X	X		X	X				X	X	X			X	X	X	X	X	X	X	16	70%	11 tied
2	Streamline project delivery meeting structure and frequency (i.e., kickoff meetings for SD, DD, and CD)	X	X	X	X	X	X	X	X									X	X	X		X	X	X	14	61%	15 tied
3	Further integrate sustainable objectives into project delivery process				X	X	X	X	X	X	X	X	X	X	X	X	X	X				X	X	X	17	74%	8 tied
4	Select core project team earlier in project process	X	X	X	X	X	X	X	X					X	X	X		X	X	X	X	X	X		17	74%	8 tied
4	Utilize subcontractor expertise to improve project design and constructability	X	X	X	X		X	X			X	X	X	X				X	X	X	X	X	X	X	17	74%	8 tied
4	Increase supplier input during design	X	X	X		X	X	X	X		X	X	X	X				X	X	X	X	X	X	X	18	78%	3 tied
5	Advance end user education regarding sustainable building objectives				X	X			X	X	X	X	X	X	X	X	X	X					X	X	14	61%	15 tied
3	Improve internal and external process communication	X	X	X	X	X	X	X	X					X				X	X	X	X	X	X	X	16	70%	11 tied
2	Research then implement alternative project delivery methods		X	X	X		X	X	X	X	X	X		X	X	X		X	X	X	X		X	X	18	78%	3 tied
1	Streamline the capital budgeting process	X	X	X	X	X	X	X	X					X	X	X		X	X	X	X		X		16	70%	11 tied
2	Decrease business case development time	X	X	X	X	X	X	X	X					X				X	X	X	X	X	X	X	16	70%	11 tied
1	Implement an integrated project team approach throughout	X	X	X	X	X	X	X	X					X	X	X		X	X	X	X	X	X	X	18	78%	3 tied
2	Streamline the second delivery transition	X	X	X	X	X	X	X	X					X	X	X		X	X	X	X	X	X	X	18	78%	3 tied
2	Work to standardize repetitive work	X	X	X	X	X	X	X	X					X	X	X		X	X	X	X	X	X	X	18	78%	3 tied

the TPS were utilized to map and assess value and waste within their sustainable building delivery process. The rigor at which the map was generated and assessed provided deep insight and understanding regarding the strategy and capabilities Toyota used to successfully deliver sustainable buildings. Apart from these successes, opportunities to eliminate process waste were also identified by the process map.

The detail of these maps allowed evaluation of the value-generating and waste-laden properties of each process. While not being particularly lean overall, the process map analysis showed that Toyota employed a small number of key lean processes: (1) Their decision to evaluate and adopt sustainable objectives very early in the process, even as early as capital budgeting; (2) the alignment of sustainable objectives to the business case of the project; (3) the identification and pursuit of building features that naturally align with sustainability; (4) the selection of an experienced design and construction team early in the project, and (5) investing time to align individual team member goals with project goals. The seamlessness of this approach is demonstrated by the fact that Toyota adopts precisely the same process regardless of whether projects pursue LEED certification or end up with few sustainable features.

Although other process models have carefully documented the building delivery process, this modeling approach and resulting process map is one of the first to examine the entire sustainable building delivery process, from building inception through turnover. This enabled unique and critical information to be obtained and allowed the evaluation of the Toyota delivery process for sustainable buildings. Unique to this evaluation is the inclusion of both the end user and environment needs in relation to value and waste.

The process map played a vital role in providing the means to identify and understand in clear terms the critical value added steps in Toyota's delivery process for sustainable buildings. This map was vital for observing many of the features of Toyota's project delivery program as the important features were not especially clear when observed through other methodologies. Through process improvement that targets increasing value and eliminating process waste, the insights gained at Toyota hold great potential for low-cost sustainable buildings throughout the AEC industry.

Acknowledgments

The writers of this paper wish to thank Toyota Motor Sales Real Estate and Facilities, and the Lean and Green Research Initiative and the Partnership for Achieving Construction Excellence (PACE) at Penn State for their support of this research.

References

Arbulu, R., and Tommelein, I. (2002). "Value stream analysis of construction supply chains: Case study on pipe supports used in power plants." *Proc., 10th Annual Conf. of Lean Construction*, August 6–8, Gramado, Brazil, Universidade Federal do Rio Grande do Sul, Brazil.

Ballard, G. (2000). "Lean project delivery system." *Lean Construction Institute White Paper No. 8*, Lean Construction Institute, Ketchum, Id.

Ballard, G., and Howell, G. (1998). "Shielding production: Essential step in production control." *J. Constr. Eng. Manage.*, 124(1), 11–17.

Ballard, G., and Zabelle, T. R. (2000). "Lean design: Process, tools, and techniques." *Lean Construction Institute White Paper No. 10*, Lean Construction Institute, Ketchum, Id.

Bremner, B., Dawson, C., Kerwin, K., Palmeri, C., and Magnusson, P. (2003). "Can anything stop Toyota?" *Business Week Online*, ⟨http://businessweek.com/magazine/content/03_46/b3858001_mz001.htm⟩ (June 9, 2005).

Hawken, P., Lovins, A., and Lovins, L. (1999). *Natural capitalism: Creating the next industrial revolution*, Little, Brown, and Company, Boston.

Hines, P., and Taylor, D. (2000). *Going lean*, Lean Enterprise Research Centre, Cardiff, U.K.

Horman, M., and Kenley, R. (2005). "Quantifying levels of wasted time in construction with meta-analysis." *J. Constr. Eng. Manage.*, 131(1), 52–61.

Horman, M., Riley, D., Lapinski, A., Korkmaz, S., Pulaski, M., Magent, C., Luo, Y., Harding, N., and Dahl, P. (2006). "Delivering green building project: Process improvements for sustainable construction." *Journal of Green Building*, 1(1), 123–140.

Horman, M. J., Riley, D. R., Pulaski, M. H., and Leyenberger, C. (2004). "Lean and green: Integrating sustainability and lean construction," *CIB World Building Congress*, May 2–7, Toronto, International Council for Research and Innovation in Building and Construction (CIB), Rotterdam, The Netherlands.

Huovila, P., and Koskela, L. (1998). "Contribution of the principles of lean construction to meet the challenges of sustainable development," *Proc., 6th Annual Conf. on Lean Construction*, August 13–15, Guarujá, Brazil.

Koskela, L. (1992). "Application of the new production philosophy to construction." *Technical Rep. No. 72*, Center for Integrated Facilities Engineering, Stanford Univ., Stanford, Calif.

Lapinski, A. R. (2005). "Delivering sustainability: Mapping Toyota Motor Sales' corporate facility delivery process." MS thesis, Architectural Engineering, The Pennsylvania State University, University Park, Pa.

Lapinski, A., Horman, M., and Riley, D. (2005). "Delivering sustainability: Lean principles for green projects," *ASCE Construction Research Congress (CRC)*, April 5–7, San Diego, ASCE, Reston, Va., 136–140.

Liker, J. K. (2004). *The Toyota way*, McGraw-Hill, New York.

Ohno, T. (1988). *Toytota production system: Beyond large-scale production*, Productivity Press, Portland, Ore.

Pristin, T. (2003). "Toyota's new main campus: Green goes mainstream." *The New York Times*, New York, C6.

Pulaski, M., Pohlman, T., Horman, M., and Riley, D. (2003). "Synergies between sustainable design and constructability at the Pentagon." *ASCE Construction Research Congress (CRC)*, March 18–20, Honolulu, ASCE, Reston, Va.

Riley, D., Magent, C., and Horman, M. (2004). "Sustainable metrics: A design process model for high performance buildings," *CIB World Building Congress*, May 2–7, Toronto, CIB, The Netherlands.

Rother, M., and Harris, R. (2002). *Creating continuous flow*, Lean Enterprise Institute, Brookline, Mass.

Rother, M., and Shook, J. (1999). *Learning to see*, Lean Enterprise Institute, Brookline, Mass.

Sanvido, V. E. (1990). "An integrated building process model." *Construction Research Program Technical Rep. No. 1*. The Pennsylvania State University, University Park, Pa.

Shingo, S., and Dillon, A. P. (1989). *A Study of the Toyota production system from an industrial engineering viewpoint*, Productivity Press, Cambridge, Mass.

Smith, A. (2003). "Building momentum: National trends and prospects for high-performance green buildings." *Rep. by the U.S. Green Building Council for the U.S. Senate Committee on Environment and Public Works*, USGBC, Washington, D.C.

Spear, S. J. (2004). "Learning to lead at Toyota." *Harvard Bus. Rev.*, 82(5), 78–91.

Spear, S. J., and Bowen, H. K. (1999). "Decoding the DNA of the Toyota production system." *Harvard Bus. Rev.*, 77(5), 96–106.

Stalk, G., Jr., and Hout, T. M. (1989). *Competing against time*, Free Press, New York.

Tommelein, I. D., and Li, A. E. Y. (1999). "Just-in-time concrete delivery: Mapping alternatives for vertical supply chain integration," *Proc., 7th Annual Conf. on Lean Construction*, July 26–28, Berkeley, Calif., University of California-Berkeley, Berkeley, Calif.

Tommelein, I. D., and Weissenberger, M. (1999). "More just-in-time: Location of buffers in structural steel supply and construction processes," *Proc., 7th Annual Conf. on Lean Construction*, July 26–28, Berkeley, Calif., University of California-Berkeley, Berkeley, Calif.

U.S. General Services Administration (GSA). (2004). "GSA LEED cost study: Final report," *Rep. No. GS-11P-99-MAD-0565*, GSA, Washington, D.C.

Womack, J. P., Jones, D. T., and Roos, D. (1990). *The machine that changed the world: The story of lean production*, HarperPerennial, New York.