

# A Lean Modeling Protocol for Evaluating Green Project Delivery

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## Abstract

The first vital step to leaning an operation is to model or map the processes used to deliver value in that operation. This allows the requisite understanding of where waste and non value-adding activity exists, and provides the foundation for improvement. Current protocols for modeling operations present the basic tenets for lean mapping, but tend to be based in manufacturing language, and are not easily adapted to capital facilities projects.

“Green” or “sustainable” capital projects delivered using current project delivery systems seem to be laden with hidden waste. These projects tend to be more challenging to deliver due increased levels of building system integration, untraditional materials, and requirements such as recycling, total commissioning, and increased project documentation. Penn State’s Lean and Green Research Initiative has examined the delivery of multi-million dollar green building projects for clients including the Pentagon, Toyota, and Penn State’s Office of Physical Plant. The processes used to complete these projects are difficult to model with current lean techniques.

This paper outlines a detailed modeling protocol for evaluating the delivery processes of green projects. Blending existing protocols and the specific needs of green building projects, this protocol will help define the data collection and analysis procedures, as well as the instruments (metrics) of analysis.

**Keywords:** Lean mapping, project delivery, green building, process modeling

## Introduction

High performance “green” or “sustainable” buildings have the potential to reduce the environmental and economic footprint of the built environment by minimizing energy use, reducing resource consumption and waste, and providing healthy and productive environments for occupants. This is vital given that buildings consume 36% of total energy use, 30% raw material use, and 12% of potable water in the U.S. (Roodman and Jensen 1995; U.S. EPA 2004). The penetration of the U.S. building construction market by green building is already significant, valued at over \$3.3 billion in 2004, and expected to reach \$10-20 billion by 2010 (McGraw Hill Editors 2005). However, this

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figure represents less than one percent of the total non-residential building market in the U.S. There is also room for growth in developing countries such as China, where the rapidly expanding \$300 billion a year construction industry currently gives almost no consideration to green building (Boardman 2005).

Yet little is known about the best processes to deliver green buildings. The greatest barrier to more widespread application of green buildings is the perception of their higher first costs (BDC Editors 2004). Research is beginning to show that delivery process features are a major factor in the increase of first cost for green buildings (Mogge 2004), and that owners modifying the traditional project delivery process to accommodate green buildings can reduce or eliminate their first cost increase for green buildings (Lapinski 2005). The building community should begin to understand the differences between traditional and green project delivery.

Lean principles can help develop a better understanding of the entire green building delivery process (i.e., from programming, planning, procurement, through design and construction to occupancy) and the cost impacts associated with this process. This paper describes the Lean and Green (L&G) protocol developed to facilitate modeling of the green building delivery process. Currently, there are no adequately defined models representing the delivery of green buildings. As a result, owners and professionals undertaking green buildings must deliver them based on their personal experiences rather than a set of standard principles. While this individualized approach can be successful in certain situations, there are problems associated with an undefined approach, the most important of which are difficulty in learning, testing, verifying, and teaching about the best processes to deliver green buildings. These difficulties are reduced or eliminated by a structured modeling approach, which also reduces instances where individual experiences are applied incorrectly to new or different situations (Alarcón 1997).

## Objectives

The objectives for this paper are to explain the development of the L&G modeling protocol and provide a template for its application. The protocol will deepen understanding of the best processes to deliver green buildings and enable information sharing across lean and green communities through a standard modeling protocol. When adopted by researchers and practitioners working with building delivery processes, the model will have a very broad impact.

## Background

### Green Building

As world population and production expand, it is critical that sustainable approaches to energy consumption, greenhouse gas emissions, and water use are developed and implemented. The green building movement is addressing these issues through efficiencies and innovations in building design, construction, and operation. Multiple definitions for green building exist, and these definitions are frequently updated. However, prominent definitions generally include the fundamental principles describing green buildings, which are synthesized in the Whole Building Design Guide and form the definition of green buildings used in this paper (NIBS 2006). Green buildings are those which:

- Optimize site potential (reduce impact on ecosystems, required transportation, and energy use through considerations of location, orientation, and landscaping),

- Optimize energy use (reduce loads, increase efficiency, and consider renewable energy),
- Protect and conserve water (minimize runoff, use efficiently, and consider reuse),
- Use environmentally preferable products (materials which have reduced impact on human health and environment when compared to equally performing materials),
- Enhance indoor environmental quality (maximize day-lighting and views, control moisture and ventilation, and minimize volatile organic compounds (VOCs)), and,
- Optimize operational and maintenance practices (take measures to minimize the environmental impacts of building maintenance and to ensure the building will operate as intended).

High performance green buildings pay particular attention to energy efficiency and indoor environment quality (Horman et al. 2006). High performance buildings are the main focus of the modeling protocol described in this paper, although the protocol could be used on other green buildings as well.

### **Need for Systematic Modeling of Green Project Delivery**

The optimal delivery processes for green buildings are not the same as those for traditional buildings. To achieve their performance benefits, green projects use intense interdisciplinary collaboration during design, highly complex modeling and analysis, and careful material and system selection particularly early in the project delivery process (Riley et al. 2004). Locally manufactured, often untraditional, and higher priced materials can be required for construction; and if certification--such as that under the U.S. Green Building Council's Leadership in Energy and Environmental Design--is sought, extensive documentation adds time and cost to the project.

The growing literature on green building offers many ideas to create green building features, but few methods for "where" and "how" green strategies should be implemented, or whether the recommended strategies will prove successful. Green requirements often incur an up-front or first cost premium (U.S. GSA 2004). This up-front cost is used to purchase better quality building components like HVAC systems and super-insulated building envelopes; "investments" that can achieve significant operational savings that extend over the life of the building.

Further adding to the upfront cost of green buildings, many green project processes are laden with wasteful rework, delays, changes, and overproduction as a result of not using the best delivery methods for these projects. Process waste can both undermine the achievement of sustainable outcomes and limit the business case for sustainability (U.S. GSA 2004; Lapinski et al. 2006).

Modeling is the critical first step to better understand green delivery processes. If process waste is trimmed from green delivery then sustainable outcomes can be enhanced without the current high first cost. For modeling to be effective, it must consider the unique attributes of the process it is representing, and a process modeling methodology for the green building delivery process should consistently represent the characteristics of green delivery processes. The Lean and Green (L&G) process modeling protocol provides a simple but rigorous methodology that conveys the complicated green building delivery process in a simple, effective style.

## Modeling Protocols

Process modeling was popularized in the development of software to: (1.) Facilitate human understanding and communication; (2.) support process improvement; (3.) support process management; (4.) automate process guidance; and, (5.) automate execution support (Curtis et al. 1992).

The application of process modeling was expanded with the realization that these contributions to software development could also be beneficial to business processes. Numerous methodologies have been employed to model various business processes and interested readers are encouraged to consult Curtis's "Process Modeling" (1992) for a more detailed review of these methodologies. It is important that the L&G modeling protocol have a firm foundation in proven modeling sciences and existing methodologies are combined and supplemented to form of the L&G modeling protocol.

Modeling influences contributing directly to the L&G protocol are listed in Table 1 along with a brief description. The source references listed in the descriptions can be consulted for additional information. Each modeling influence listed in Table 1 is required to satisfy the expectations developed for the L&G protocol (Table 2).

## Lean and Green Modeling Protocol

### Goals and Requirements

The goal for the L&G protocol is to enable representation (current state maps), analysis, and improvement (future state maps) of the green building delivery process. This goal will be accomplished through incorporation of lean principles including:

- **facilitation of visualization and process transparency** (L&G models display processes in a format easily understood by those outside the building industry),
- **display of value adding activities** (L&G models incorporate the voice of the customer to identify value, then display processes that contribute to customer value),
- **display of wasteful activities** (Processes in L&G models not contributing to customer value are wasteful),
- **use of relevant metrics for process control** (L&G models help with metric application by clearly defining the process for measurement), and
- **analysis for optimized placement of added processes** (By defining the process, L&G models enable scientific evaluation of the best location for adding activities - energy modeling for example - essential to green building delivery.)

The associated targeted result of the L&G protocol is a straightforward, intuitive representation of the green building delivery process for application by researchers and industry professionals to compare, analyze, and improve green building delivery processes.

Table 1: Modeling Influences

Influence	Description
Integrated DEFinition method 0 (IDEF0)	A series of diagrams first showing processes at a high level and then decomposing them down to a series of sub-processes (Sanvido 1990)
Integrated Building Process Model (IBPM)	Applies the IDEF0 methodology in outlining the primary activities required to deliver a building (Sanvido 1990)
Flowchart	A graphic representation, using symbols and connectors, of a process (Damelio 1996)
Value Stream Mapping (VSM)	A process mapping tool, based on the concept of lean, focusing on a total process perspective and elimination of waste in manufacturing processes (Hines 2000)
Value Stream Mapping for Product Development (VSMPD)	A process mapping tool that adapts VSM for application to production processes (Morgan 2002)
Production Model	A process model that considers the differences between manufacturing and construction processes (Koskela 1992)
US NAVAl FACilities engineering command (NAVFAC)	Process mapping applied to investigate NAVFAC's green building delivery process (Sanders 2003)
Toyota Real Estate and Facilities (RE&F)	Process mapping applied to investigate RE&F's green building delivery process (Lapinski 2005)
Salford	A generic process sequence for delivering sustainable facilities (Salford 2002)
Swimlanes	Horizontal lines added to process maps that enable representation of which group performs each task (Cordes 1998)
Information Sheets	Detailed written descriptions of an activity in a process map (Pojasek 2004)

## Value Criteria Selection

Critical to the L&G modeling protocol is development of an understanding of what adds value for the customer. The final customers in green building delivery are the owner and end-users of the building. Lean theory defines value creation as providing for the customer the right product and/or service, at the right time, with the right cost (Womack and Jones 2003). Based on lean theory, value creation for the building end-user involves obtaining the building they specified, on time, and at the least possible cost.

The L&G protocol will apply "Voice of the Customer" (VOC) as a tool to help define end-user value. VOC complements lean theory, soliciting customer input to determine exactly what the customer's needs are, and then using this input in product design. VOC is determined through either reactive (formal and informal complaints) or proactive (interviews, surveys and focus groups) measures (George 2003). After the VOC is determined, the L&G protocol will apply Quality Function Deployment (QFD) to

translate needs identified through VOC into technical requirements for green building delivery.

Typically, costs associated with financial and manufactured resources are considered in value analysis. However, the L&G protocol also considers customer value associated with human and natural resources. In particular, the L&G protocol considers financial, manufactured, human, and natural resources in value determination concerning the environment. There is value to the building end-user in the generation and preservation of each of these resource types and there is waste in activity that absorbs these resources without providing value in return.

Table 2: L&G Modeling Expectations and Influences

	Modeling Influences	IDEF0 Foundation	IDEF0	IBPM	Flowchart	VSM Foundation	VSM	VSM/MPD	Production Model	Green Building Delivery	NAVFAC	RE&F	Salford	General	Swinlanes	Info Sheets	Green
<b>Modeling Requirements</b>																	
<b>Technical merit</b>																	
T1	Is easily integrated					●											
T2	Has sufficient breadth		○			●		○		-							
T3	Has sufficient depth		○			●	○		-	-	○						○
T4	Is decomposable		●			○											
T5	Is modular		●			○											
T6	Is extendable							○	○							●	
T7	Is quantifiable							○	○	○							
T8	Considers all value types												○				●
<b>Ease of use</b>																	
E1	Follows simple modeling rules		○	○		●		○	○	○							
E2	Is supported by computer tool																
E3	Is easy to follow, clear		-	-				○	○				●	○			
E4	Minimizes mapping time					○		●	○								
E5	Demonstrates process flow							●	○	○			○	-			
E6	Differentiates value and waste		-	-				●	○	○			○				
<b>Suitability for owners</b>																	
S1	Represents entire delivery					●		○	○				○	○			
S2	Represents all orgs. projects					○		○	○				●	○			
S3	Is specific to green building							○	○				●	○			○
S4	Increases process transparency							○	○				●	○			
S5	Is flexible		-	-		○		○	○	●							○
S6	Considers the audience					○							●	○			
<b>Perspectives</b>																	
P1	Behavioral							●	○				○				
P2	Organizational (internal)												○	●			
P3	Organizational (external)															●	
P4	Informational																●
P5	Functional		●	○	○			○	○				○	○			

**Key**

- Primary satisfier
- Satisfies, not primary
- Does not satisfy
- Blank Cell N/A

**Relation to Existing Models**

To satisfy the goal and achieve the targeted result of the L&G protocol, modeling expectations were developed and categorized within; (T) Technical merit, (E) Ease of

use, (S) Suitability for owner organizations delivering green buildings, or (P) demonstration of required Perspectives. Table 2 lists these expectations in the two left columns. For example, expectation T1 requires that models created by the L&G protocol can easily integrate with other models created by the same protocol. Satisfying this expectation will allow the combination of modeling from multiple organizations to create a single model representative of the green building delivery process.

To test for internal validity of the L&G modeling protocol, it was evaluated whether the protocol satisfies the expectations specific to the L&G research initiative. The matrix section of Table 2 demonstrates how each L&G modeling expectation is satisfied by at least one modeling influence. For example, we see that the IBPM influence is the primary satisfier of expectations T1 (is easily integrated), T2 (has sufficient breadth), T3 (has sufficient depth), and S1 (represents the entire delivery process.) However, the IBPM alone cannot satisfy all of the expectations of the L&G protocol and the VSM influence is the primary satisfier of expectations E4 (minimizes mapping time), E5 (demonstrates process flow), E6 (differentiates between value and waste), and P1 (demonstration of behavioral perspective.)

While Table 2 shows how the L&G protocol influences contribute to L&G mapping, Figure 1 demonstrates the relationships between the influences. IDEF0 and Value-Stream Mapping (VSM) form the foundation for the protocol. The IDEF0 methodology is a series of diagrams first showing processes at a high level and then decomposing them into a series of sub-processes. VSM is a mapping methodology based on lean principles that originated in manufacturing and demonstrates total process flow while enabling identification of value and waste.

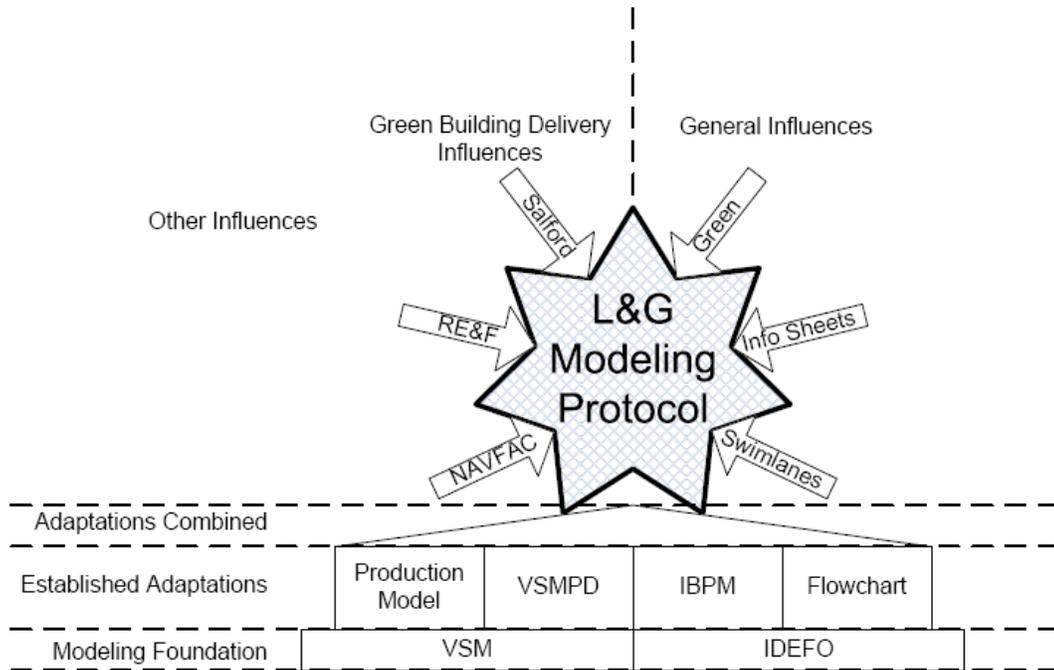


Figure 1: L&G Modeling Influence Relations

Directly above VSM and IDEF0 in Figure 1 are: Flowcharting; the Integrated Building Process Model (IBPM); Value Stream Mapping for Product Development (VSMPD); the Production Model; and Phase Scheduling. Flowcharting provides a simple, detailed capability to the L&G protocol. The IBPM is an adaptation of IDEF0, representing all of the tasks required to deliver a building (Sanvido 1990). VSMPD is an adaptation of VSM

that is appropriate for product development (Morgan 2002), which is more similar to building delivery processes. The Production Model further adapts VSM, addressing the differences between manufacturing and construction processes (Koskela 1992). Combined, these adaptations provide the primary influence for the L&G protocol.

The remaining influences for the L&G protocol are divided into general influences and green building delivery influences. Because of the lack of relevant published research, green building delivery influences on the L&G protocol are limited to research done at the University of Salford, at Toyota Real Estate and Facilities (RE&F,) and at Naval Facilities Command (NAVFAC.) Research at Salford produced a series of process sequences illustrating the phases that may be undertaken during green building delivery (Salford 2002). At Toyota RE&F, Penn State researchers mapped the delivery process, examining how Toyota delivers green buildings with no additional first cost to the project (Lapinski 2005). Penn State researchers at NAVFAC applied process modeling in an effort to provide recommendations on how to incorporate sustainability into the Naval facilities acquisition process (Sanders 2003). General influences include:

- Swimlanes, which are horizontal lanes added to the model representing the organization responsible for each process (swimlanes are borrowed from deployment flowcharting, developed by W. Edwards Deming, and popularized in the U.S. by his disciple Myron Tribus (Cordes 1998)),
- Information accounting sheets describing each sub-process activity in detail (Pojasek 2004), and,
- Green influences, described in more detail in the next section.

## Green Influences

Requirement T8 of the L&G protocol is recognition of all types of value and waste in terms of human, financial, manufactured, and natural resources. This ability is crucial to obtain an accurate measure of value and waste for any process, and is especially important in analyzing processes, like green building delivery, with green products. To accurately assess value and waste, value must be assigned to natural resources (living systems) and human resources (social and cultural systems) that are the basis of human existence (Hawken et al. 1999). If all resource types are not considered, delivery factors that may impact the environmental, or “green” values to the customer (e.g., environmental burdens in operation, service life, risk of deterioration, convertibility, and flexibility) are overlooked. To emphasize this point, Table 3 provides examples of value and waste, specific to green building delivery, in each of the four resource types.

Previous green building mapping efforts added the environment as a customer to account for needs specific to green building delivery (Lapinski 2005). Now, in the L&G protocol, all of the environment’s needs are expressed through the natural and human resources needs of the building users. For example, reduced greenhouse gas emissions resulting from decreased energy use are now considered as a natural resource need for the building user rather than a requisite of “the environment.” This change clarifies the link between users and natural resources and, by limiting the number of customers, streamlines the mapping effort.

## Modeling Components

L&G modeling begins with development of the macro level process overview (level 1 mapping) and continues with micro levels (levels 2 and 3 mapping) in increasing amounts of detail. Level 1 mapping displays a value-stream perspective of the overall

green building delivery process. This prevents a common problem in mapping exercises where sub-processes are optimized locally at the expense of the overall system performance (Arbulu and Tommelein 2003). For each macro-level process, a level 2 map is developed showing the associated sub-processes. At the top of each level 2 map, a Reference Key enables the reader to maintain a big-picture understanding of the map location in the overall delivery process.

Table 3: Green Influences on L&amp;G Modeling Protocol

Resource	Examples	Value Example	Waste Example
Human	Labor, intelligence, culture, organization	Workshops educating occupants on the benefits of green buildings	Ignoring contractor's knowledge during building design.
Financial	Cash, investments, monetary instruments	Requiring cost estimates from multiple contractors.	Late identification of green goals - when they cost more to achieve.
Manufactured	Infrastructure, machines, factories	Constructing a building.	Demolition of a building suitable for renovation.
Natural	Living systems, ecosystem services	Energy modeling to reduce energy consumed.	Oversizing an HVAC system.

## Icons

Icons used in L&G modeling are shown in Figures 2-3. The appearance of the icons needs to be easily understood by the organization using them. For example, many standard icons typically chosen for value stream mapping are based on a manufacturing environment and are not the best choice for use in a construction organization.

## Rules

Rules for the L&G protocol are minimized for modeling simplicity and to reduce opportunities for modelers to inadvertently break these rules. L&G rules to guide map development are:

- a process must start with an input and have at least one activity and output,
- the output of one process must be the input of another process,
- an input must be succeeded by a process and cannot be succeeded by an output,
- a process must be succeeded by another process, a decision, or an output, and,
- an output must not be succeeded by another output.

## Boundaries

Essential to any process modeling exercise is definition of the modeling boundaries (Tang et al. 2004). Definition is especially important in the modeling of building processes where significant inefficiencies occur around the boundaries of processes, disciplines, and organizations (Arbulu and Tommelein 2003, NIST Editors 2002). The

structure of the L&G protocol enables modeling to continue through internal boundaries between levels, processes, departments, and organizations. The L&G protocol ends only at external boundaries, (prior to conception of a building and after the building's useful life).

## **Modeling Format - Data Collection and Display**

To begin development of maps using the L&G protocol, modelers must first become familiar with the organization being modeled so that the value of time spent with members of the organization is maximized. Initial data collection can include observation from within the organization being modeled and must include review of applicable organizational procedure manuals, standard forms, meeting minutes, project records, and schedule templates. In the case of practitioners mapping processes within their own organization, this initial organizational study is unnecessary.

### **Level 1**

After a basic understanding of the organization is achieved, the modeler can begin development of a Level 1 map. Interviews with an employee who understands the basics of an organization's overall delivery process, typically a high-level executive, are effective in developing the level 1 map. An initial two hour interview session is sufficient to provide information for development of a draft level 1 map, and a follow-up one hour session will clarify that the draft map represents the interviewees understanding of the overall delivery process. Figure 2 provides an example of data collected for a Level 1 map created for Penn State's Office of Physical Plant, while Figure 2A displays the resulting Level 1 map.

Questions to ask in the level 1 and level 2 mapping interview sessions are adopted from VSM due to its focus on understanding the overall system perspective. Hines and Taylor's (2000) general questions in their seminal work "Going Lean" focus on understanding customer requirements, information and physical flows, and links between these flows to create a big picture map. These questions can be tailored to green building delivery and combined with questions from the green delivery mapping at Toyota RE&F (Lapinski 2005). Modelers can also apply their familiarity with the organization to be mapped and their knowledge of lean mapping principles to develop questions suitable for their specific situation.

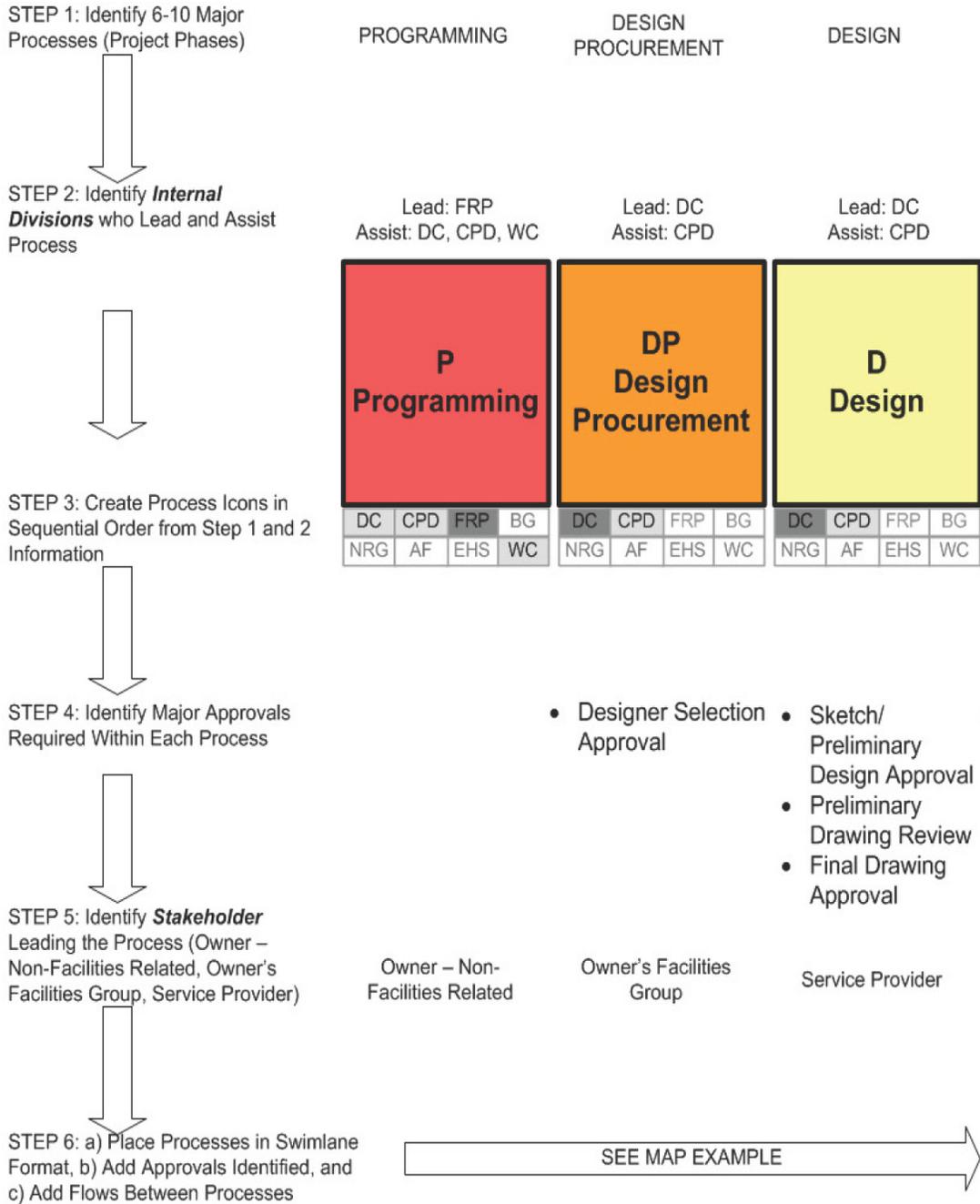


Figure 2: Level 1 Mapping Data Collection (For visual clarity, this figure represents only a section of OPP's delivery process. Complete maps are available from the author by request.)

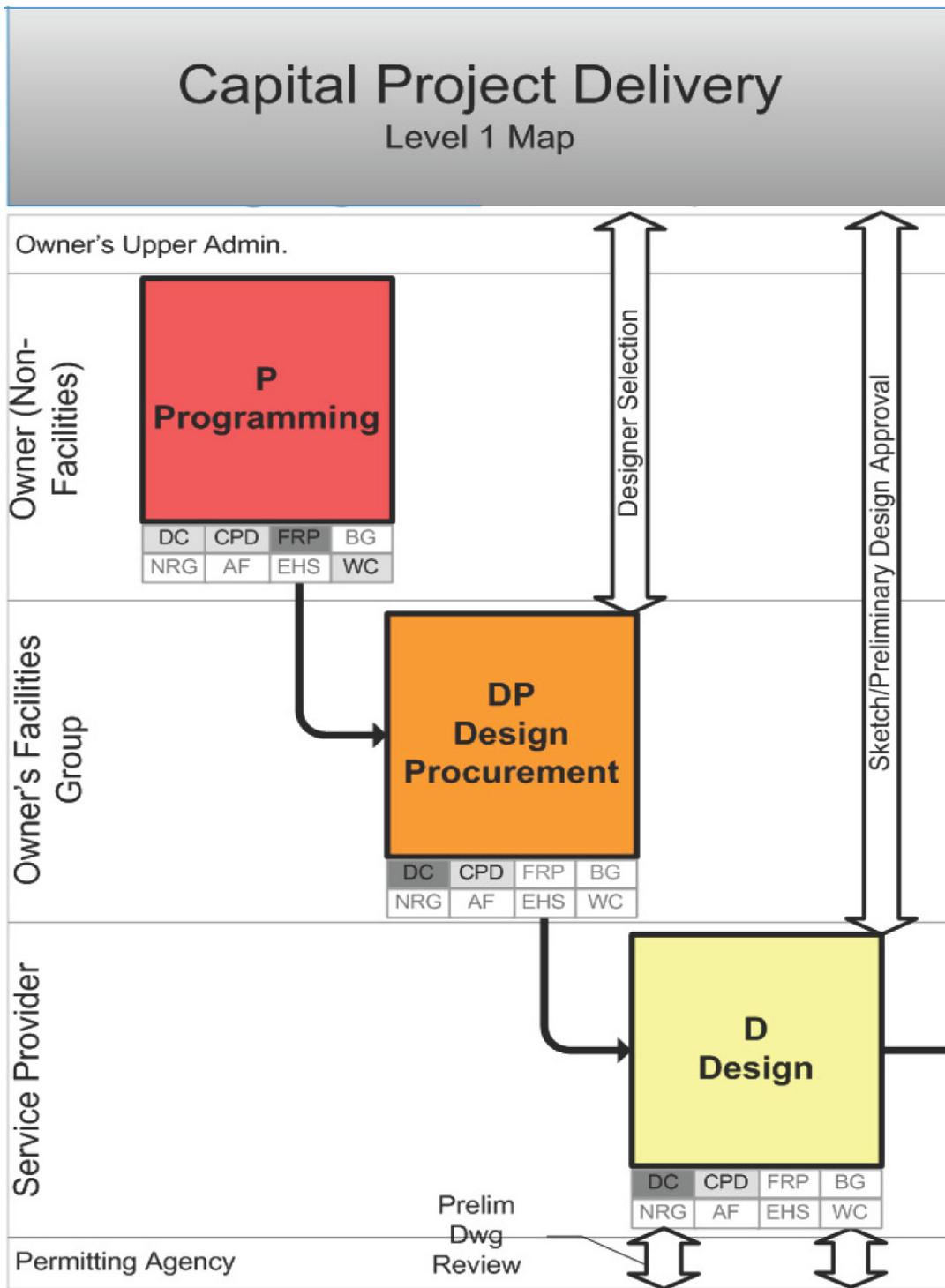


Figure 2A: Level 1 Map (For visual clarity, this map represents only a section of OPP's delivery process. Complete maps are available from the author by request.)

## Level 2

At the end of the second level 1 mapping meeting, the modeler should work with the interviewee to identify an interview subject for each of the processes in the level 1 map. To obtain the most accurate maps, these interviewees are the members of the organization that best understand the applicable process. For example, it is likely that the organization members that best understand the programming or planning process are different from the members who best understand the construction process. With each of the level 2 interview subjects, the modeler should follow a similar procedure to that employed for the level 1 mapping, gathering information from an initial two hour meeting and a follow-up one hour meeting to complete a level 2 map. Figure 3 provides an example of data collected for a Level 2 map created for Penn State's Office of Physical Plant, while Figure 3A displays the resulting Level 2 map.

## Level 3

To create detailed level 3 maps, it is no longer sufficient to rely exclusively on senior managers as we did in levels 1 and 2 mapping. The front line workers involved in the day to day operations of the sub-process being mapped must be consulted to get a complete picture of what actually happens in the process (Hines and Taylor 2000). To address this issue, multi-disciplinary teams are formed that are familiar with a specific sub-process being mapped. With the aid of these groups, maps for each sub-process are created and verified (Rother and Shook 1999). Data collected for and formatting of Level 3 maps follows the same procedure as outlined for Level 2 in Figures 3 and 3A.

## Future Plans - Map Analysis

Developing process maps using the L&G protocol is the crucial first step in understanding and improving green building delivery. The map development process itself will likely have immediate benefits to organizations employing it, increasing understanding of their processes. However, the majority of expected benefits will be realized after completion of the initial mapping. Completed maps will provide "transparency" (a visual representation of the entire process) for all stakeholders in the delivery of green projects. This whole-process perspective is crucial, as stakeholders with a better understanding of the entire process, and their role within it can contribute to a more efficient process. More importantly, completed maps will allow analysis for potential changes aimed at making the process more effective. Steps deemed as wasteful or non value adding to green building delivery can be removed to streamline the process. Also, strategies recommended for delivering green buildings (ex. energy modeling) can be placed optimally within the process models and analyzed for value-added. Future-state process maps, where wasteful activities are removed and required strategies are added in their optimal location, will guide a more efficient and effective green building delivery process.

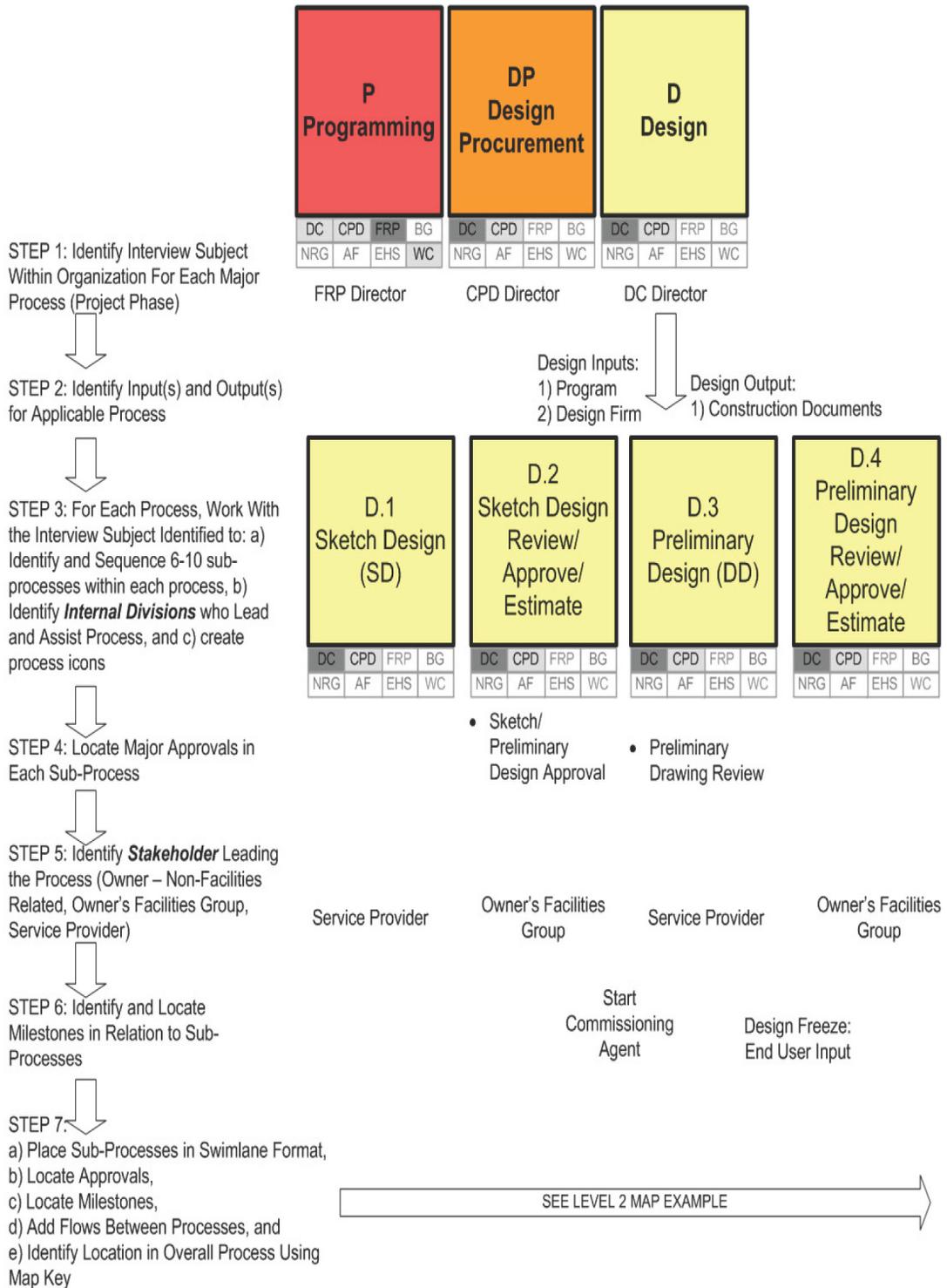


Figure 3: Level 2 Mapping Data Collection (For visual clarity, this figure represents only a section of OPP's design process. Complete maps are available from the author by request.)

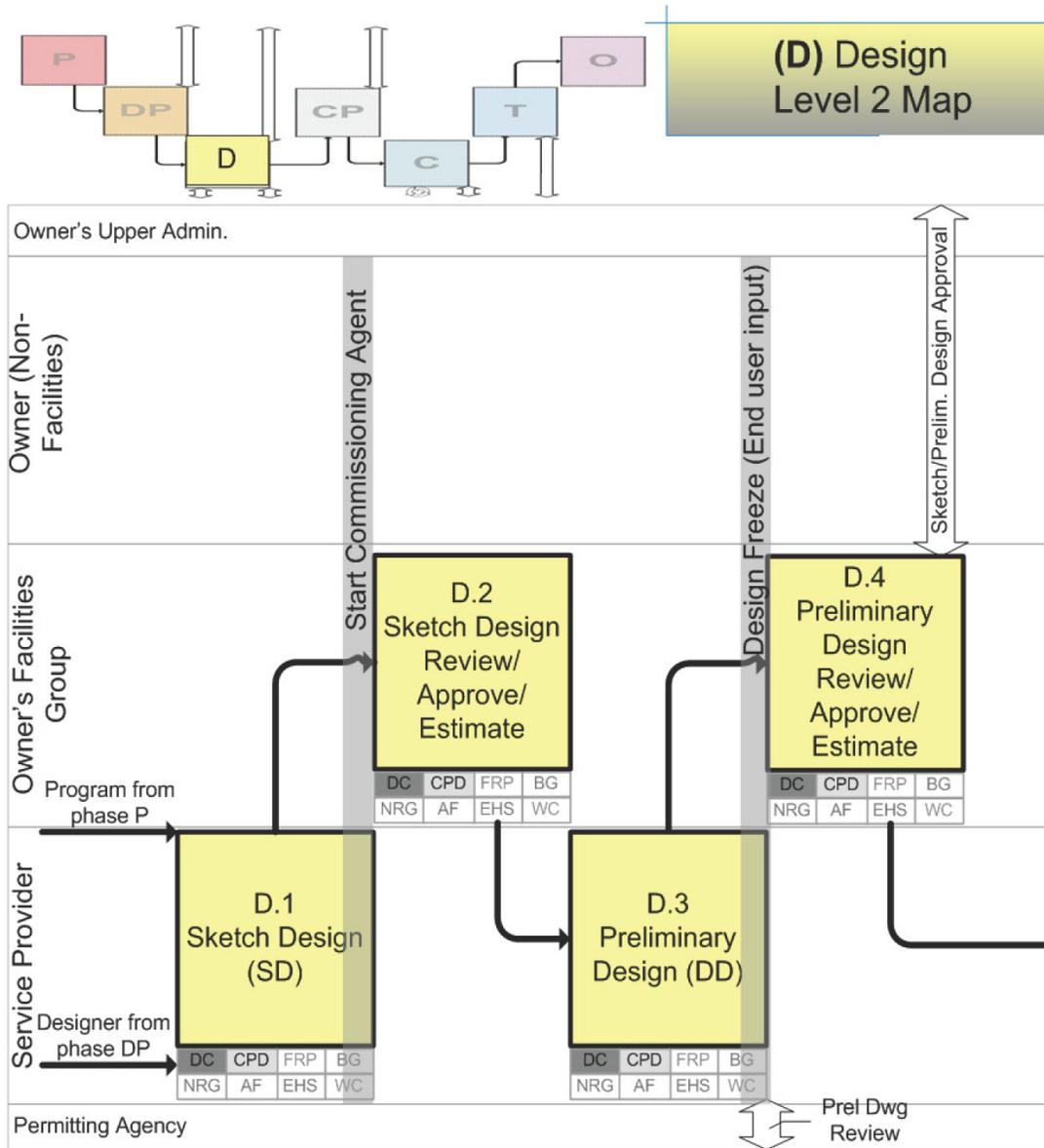


Figure 3A: Level 2 Map (For visual clarity, this map represents only a section of OPP's design process. Complete maps are available from the author by request.)

## Limitations

All major parties involved in the delivery of green buildings are represented in the swimlanes of the L&G protocol maps. However, the mapping examples described in this paper are developed from an owner's perspective. In the future, testing of the L&G protocol will be expanded to include mapping from the perspective of architects, contractors, suppliers and other organizations in the supply chain of construction projects. Adding perspectives helps with comparison of tasks being performed by various groups to identify duplication of work, a problem that plagues building delivery (NIST Editors 2002). For example, a recognized inefficiency in green building delivery is in the transfer of information from the owner to the architect and from the architect to the

contractor (Mogge 2004). It is a basic tenet of value stream mapping that customers and suppliers should be involved in the coordination of the supply chain to reduce this waste between companies (Jones and Womack 2002). In the building industry, extension of the value stream is recognized as a necessity due to the fragmented nature of the industry (Arbulu and Tommelein 2003).

## Conclusions

The optimal processes to deliver “green” or “sustainable” capital projects are not the same as those for conventional buildings. Green projects tend to be more challenging to deliver due to the unusual and non-traditional requirements of green buildings. Using conventional delivery methods results in process waste on green projects that reduces levels of sustainability and unnecessarily increases project costs.

In order to understand how best to deliver green buildings, this paper outlined a modeling protocol. The development of this modeling protocol attests to the maturation of lean practices in construction. As lean proponents seek to make the next wave of enduring process improvements, detailed practices, attuned to the particular conditions of capital facilities projects, are being developed. These detailed mapping practices are a required first step in improving the green delivery processes, facilitating understanding of the processes for improvement.

A conceptual connection between the end user and the environment was drawn in relation to process waste reduction. By identifying and eliminating waste, sustainable outcomes can be enhanced through utilizing delivery processes that are better equipped to maximize value generation by fulfilling the unique needs of green building projects.

The L&G modeling protocol satisfies these needs while serving as a template for L&G researchers to map individual projects and enabling development of a process model to understand green building delivery. Researchers as well as industry can apply the protocol to map and improve their green building delivery processes and to compare their process maps to those developed by L&G for further improvement.

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