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Target Value Design Inspired Practices to Deliver Sustainable Buildings

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Abstract: The design of environmentally-friendly buildings relies on the work of interdisciplinary teams who have to look at problems in a holistic way. Teams need to communicate, collaborate, and make decisions not solely based on first cost considerations. For this purpose, Target Value Design (TVD) related practices are being used to deliver green buildings in Southern California while meeting strict code requirements and addressing the needs of multiple stakeholders in a collaborative fashion. This study did not quantify costs associated with design and construction of sustainable buildings. It used an analytical process that compared and contrasted available literature on TVD and interviews with industry practitioners to investigate the use of TVD-inspired practices in the construction industry in Southern California and identify the current use of TVD-inspired practices in the design of green buildings. The study revealed that, even though practitioners might not be aware of how TVD can be fully implemented in these projects, a number of TVD-inspired practices are currently being used. Examples are provided to illustrate their practical use in the design of sustainable buildings and how practice compares to theory regarding TVD implementation.

Keywords: lean construction; Target Value Design; sustainable buildings; collaboration

1. Introduction

Target Value Design (TVD) draws its origins from Toyota's target cost in the manufacturing industry. It essentially means designing to the client budget instead of estimating the cost of the design and later readjusting the design to address cost overruns, which generate rework for the design team. According to Ballard [1], research on TVD has been largely limited to healthcare and educational facilities, but this study aims to understand if and how TVD can also be implemented to assist with the design and construction of green buildings in other sectors. A full TVD process already exists as a benchmark for the construction industry at large [2]. However, this study also aims to detect if there are variations or gradations of TVD implementation, which are referred to in this study as "TVD-inspired" approaches identified in the geographical area where the study was developed.

In the context of this study, the terms sustainable buildings, green buildings, and environmentally conscious buildings are used interchangeably. These buildings are designed, built, and operated using materials, processes, and systems that are environmentally conscious. This results in the consumption of fewer resources during their life cycle, lower impacts on their surrounding environment and users, and promotion of the health and safety of its occupants. These buildings are not perfectly sustainable in the sense that they would be self-sufficient and/or have zero or positive impact in the environment. However, they are designed, built, and operated using environmentally conscious solutions to the extent possible given current conditions of the construction industry.

Even though green buildings are gradually becoming more present in the agenda of Owner, Architect, Engineer, and Construction (OAEC) groups worldwide, their cost is still perceived to be a problem. One of the main reasons for that is the fact that green features are not integrated early in the design process and green features might be added to the project later on top of an existing design, which sometimes is so advanced in its development that it makes implementation of green features unfeasible [3]. Understanding that building systems are interconnected and dependent on each other should be a categorical design rule for any project whether a green building or not. However, for green buildings, this understanding is even more important since not taking advantage of those synergies can make reasonable costs unfeasible. An integrated design approach seems to be the clear path to achieve higher levels of building performance, human performance, and environmental benefits [4].

The need for interconnectivity between building systems calls for increasingly sustainable buildings capable of achieving substantial energy savings [5] and meeting progressively strict code requirements such as the California Building Code—Title 24 [6]. Design and construction developed in this context can benefit from TVD-related practices, which foster collaboration, take advantage of synergies between systems, and support the constant management of costs to deliver value with a minimal waste of resources [1,2]. Accordingly, the following questions are addressed in this study:

- How do the demands placed on companies in the geographical subdivision where this study took place (Southern California) affect the industry approach to design and build green buildings?
- Which practices identified in the literature and elicited from interviews with industry practitioners do support the implementation of TVD-inspired processes in the delivery of environmentally-friendly buildings?

2. The Impact of California Title 24 in Green Build Awareness

California became the first state in the United States to approve a strong energy efficiency building code in 1978. Over the years, Title 24 has continuously pushed the industry limits to deliver buildings with increased performance and lower environmental impact. This scenario sets California as a nationwide and, arguably, one of the world leaders on implementation of green building features and initiatives [7].

The California Green Building Standards Code, which is also known as "CALGreen" [6], was added to the 2010 Edition of Title 24 and constitutes the first statewide green building code in the United States. The influence of Title 24 on advancing green buildings goes beyond the state limits. The Leadership in Energy and Environmental Design (LEED) from USGBC states in its Minimum Energy Performance Prerequisite that projects in California shall meet this certification requirement by surpassing Title 24, Part 6 (Energy Code) by 10%. Meanwhile projects located anywhere else are required to exceed the ASHRAE Standard 90.1 instead [8]. Per Executive Order S-20-04 (2005) [9], all new and renovated state buildings in California are required to be LEED Silver at a minimum. Many U.S. states are adopting energy efficiency mandates for public buildings through legislation or an executive order.

3. Lean Construction Practices and the Design of Green Building

The use of Lean Construction practices to improve the delivery of projects has been highlighted as one of the forces driving collaboration across the OAEC industry alongside the demand for sustainable projects and the use of technology [10]. Environmentally-friendly buildings rely on the work of interdisciplinary teams. They address carbon footprint, energy and water consumption, emissions associated with construction materials, and how all those items interact with each other. Specialty teams have to look at problems in a holistic way rather than solving them individually for the sole purpose of their discipline. Teams need to communicate, collaborate, and interact more often.

In collaborative projects supported by the use of Lean practices, team members are often co-located in the same physical space [11] and use Target Value Design practices, which are discussed later in this document, to obtain a more realistic project in terms of goals, scheduling, and budgeting [12].

These project environments have their production systems designed using Lean principles to support collaboration in different phases of the project from design through construction and even operation.

In this environment, the use of Lean concepts and principles to design production systems and improve processes that deliver products and services calls for the management of three important aspects of production systems such as transformation (T), flow (F), and value (V) [13], which are discussed below.

- Transformation—is the core activity in a production process, which is usually the only one that adds value. It consists of the conversion of inputs (e.g., labor, material, equipment, and information) into outputs (e.g., design details and physical elements at the site). For instance, the conversion of sheet metal into air ducts and the conversion of industrial wood into doors and windows are examples of transformation.
- Flow—is the movement of material, information, or equipment through the system. Materials enter the system as raw material (input) and are released as an end product (output). At any point during the flow, the material is either being processed (converted), inspected, waiting, or moving (being transported). The sequence of construction/design activities has a direct impact on the production flow. For instance, if electrical roughing is scheduled for Wednesday and by then the drywall is not installed, that will disturb the production flow and cause delay in the construction schedule. The management of flows in a production system supports continuity, reliability, and timely resolution of issues by avoiding unnecessary tasks and their related costs [14].
- Value—refers to what is important to the customer as far as the fulfillment of their requirements. For example, a specialty contractor can provide a flooring system that will cost half the price of vinyl flooring specified in the construction documents. The project is a hospital and has to meet a plethora of regulations that can only be achieved if the vinyl flooring is used. Therefore, while less expensive, the alternative flooring system has no value for the client because it will not meet their needs and purpose. In a Lean construction environment, the job of the project delivery team is also meant to educate the customer about what they want based on the purpose of their business plan [15].

An efficient production process is achieved in part by enhancing the conversion activities and reducing or eliminating the share of non-value adding work (i.e., waiting, transportation, and inspection). Nevertheless, it is important to note that even activities that do not add value sometimes still need to be performed depending on existing work conditions. For instance, if suppliers are not properly vetted by the owner who furnishes materials to a project, construction personnel will have to perform material inspections at the site to assure that the materials are appropriate for installation at the project.

Target Value Design

The standard industry practice is to produce project design drawings to a certain level of completion, estimate their cost, and then adjust them fit the project's budget, which is a very wasteful approach. Basically, in this process, the costs of the design elements are summed up and that defines how much the project will cost. Conversely, design to a target cost is a product development practice that can be understood as part of a research field called Design for X (DfX), which means design for target characteristics. In this case, the target characteristic is the cost [16]. TVD relies on "clusters" of collaboration organized by systems (e.g., envelope, structure, mechanical) and composed by cross-disciplinary members who are jointly responsible for providing updated design and estimates as needed [17].

Tillmann et al. [18] have found that production costs in TVD appear to depend on three major components: (a) product design, which impacts costs associated with the building design itself, (b) process design, which impacts the costs of the building production system, and (c) service design, which influences costs to maintain the temporary organization of people necessary to design and build the facility. These factors are largely associated with the project's general conditions.

One of the main aspects that sets TVD apart from other methods is the fact that it uses cost as an input instead of an output to the project development process [18]. TVD transcends the simple notion of cost by making clear that performance and value are also part of the equation and should, therefore, be considered during decision-making in the design process.

In fact, a study conducted by Zimina et al. [17] showed an average cost reduction of 15% below market value in the final cost of projects that performed a systemic application of Target Value Design. Another research study presented by Do et al. [19] using a sample of 47 projects found that TVD projects have, on average, 3.5% construction contingency while non-TVD projects have 7.9% construction contingency. To be effective, the TVD process needs to happen throughout all the project phases where the team will set targets, design to targets, and build to targets. This is also related to the idea of designing processes and products side-by-side, which is proposed by Tsao et al. [20] in their discussion about Work Structuring.

To support the discussion presented in this study, a review of the literature about TVD and its related principles is summarized in Table 1. Additional references might offer a compilation of TVD principles. However, the three sources presented herein offer a comprehensive list whose principles are often referred to in other studies about TVD. The table is organized by: references (e.g., A. Macomber et al. [21], B. P2SL [22], C. Ballard [1]), codes associated with each reference and practice (e.g., A1-15, B.1-5, C.1-17), interactions between different practices that are closely related (e.g., A.1 Engage deeply with client, A.10 Engage client as a key performer, C.7 Have the customer be an active and permanent member of team), and potential beneficial outcomes that result from the implementation of each practice.

The interactions in Table 1 represent TVD practices that appear repeatedly across the three references shown. A closer look at Table 1 reveals that work in cross-functional teams, collaborative planning of goals, and capturing lessons learned appear the most (four interactions each). In fact, those are core TVD practices that support the Lean aspects of transformation, flow, and value (TFV), which were previously discussed. Some examples of how these core TVD practices support TFV are: (1) by recognizing that a diverse group of experts can achieve more constructible design solutions (transformation, flow, value), (2) by monitoring construction activities so they happen in the most effective sequence (flow), and (3) by helping the team stay focused in what is best for the project (value).

Table 1. TVD Benchmark Practices.

			Interactions	TVD Practice	Outcomes
A. Macomber et al. [21]	**Foundational TVD practices**	A.1	A.1/A.10/C.7	Engage deeply with client.	Constant pursuit of greatest value.
		A.2	A.2/A.9/A.12/B.4	Keep track of lessons learned.	Spurs innovation.
		A.3	A.3/B.5/C.15	Design to a detail estimate.	Avoids estimating a detailed design, which can be wasteful.
		A.4	A.4/A.7/B.2/B.3	Spend time in planning and do it collaboratively.	Saves money in execution.
		A.5	A.5/A.14	Design product and process concurrently.	Streamlines submittal approval.
		A.6	A.6/A.11	"Pull" instead of "push" the design.	Keeps the focus on priorities and values to client.
		A.7	A.7/A.4/B.2/B.3	Work in small and diverse groups.	Considers diverse points of view.
		A.8	A.8/C.17	Work in a big room.	Quicker answers, strengthen relationships, trust building.
		A.9	A.9/A.2/A.12/B.4	Plus and delta activity after milestones.	Formal retrospective that helps better retain lessons learned.
	Advanced TVD practices	A.10	A.10/A.1/C.7	Engage client as a key performer.	Timely decision, clear vision, and well-defined project goals.
		A.11	A.11/A.6	Design in small batches.	Shorter learning cycles and less mistakes carried downstream.
		A.12	A.12/A.2/A.9/B.4	One-page improvement reports.	Captures and share learning.
		A.13	A.13	3P (Production Preparation Process)/Mockups.	Enhanced constructability, which is highly valued among customers.
		A.14	A.14/A.5	Set-based design using A3 thinking.	Quick conveyance of design alternatives and its implications.
		A.15	A.15	Choosing by Advantages (CBA) decision-making.	Sound decisions based on Life Cycle. Assessment (LCA) instead of first cost, objective criteria.
B. P2SL [22]		B.1	B.1/C.4	Timely involve key participants (not too soon, not too late).	Educated decisions. Cost impact is lower early in the design phase.
		B.2	B.2/A.4/A.7/B.3	Collaborate.	Everyone has something valuable to contribute.
		B.3	B.3/A.4/A.7/B.2	Develop goals collaboratively.	True commitment in following project purpose and constraints.
		B.4	B.4/A.2/A.9/A.12	Pursue continuous improvement.	Uncovers deficiencies early so they are not carried downstream.
		B.5	B.5/A.3/C.15	Steering design to a target value.	Greatest possible value at the lowest possible cost.

Table 1. *Cont.*

		Interactions	TVD Practice	Outcomes
C. Ballard [1]	C.1	C.1	Define market and allowable cost.	Cost gap will inform whether to fund a feasibility study.
	C.2	C.2	Business case evaluation: fund a feasibility study?	Increased chance of project success due to a more realistic analysis.
	C.3	C.3	Build business case based on operations model.	Increased life cycle benefits.
	C.4	C.4/B.1	Involve all key stakeholders in feasibility study.	More acceptance by the group.
	C.5	C.5	Align project ends, means, and constraints.	Better information on how feasible it is to fund the project.
	C.6	C.6	Detailed budget and schedule borne from feasibility study.	Better alignment with project scope and quality requirements.
	C.7	C.7/A.1/A.10	Have the customer be an active and permanent member of team.	Keep focus on what is valuable for the owner.
	C.8	C.8	Clearly set project goals and client's vision.	All team members understand the business case and project values.
	C.9	C.9	Relational contract.	Aligns the interests of project team members with the project objectives.
	C.10	C.10	Only the client can change scope, quality, cost, and schedule.	Assures high performance of Design and Construction (D&C) process.
	C.11	C.11	Discuss cost, quality, and schedule implications of design alternatives before major investments of design time.	Ensures cost, quality, and schedule control.
	C.12	C.12/C.16	Continuous estimating.	Collaborative estimating.
	C.13	C.13	Use Last Planner System®.	Better coordination of the actions of team members.
	C.14	C.14	Set a few stretched goals.	Spurs innovation.
	C.15	C.15/A.3/B.5	Assign target scope and cost to cross-functional teams.	Enhanced constructability and cost-effectiveness.
	C.16	C.16/C.12	Update estimate to reflect TVD team updates (@3weeks max).	Enhanced cost control. Use plus/minus report.
	C.17	C.17/A.8	Co-location	Quicker answers, strengthens relationships, trust building.

4. Research Method

The study used qualitative methods to gather and analyze data. According to Rossman and Rallis [23], qualitative research data has the following characteristics, which are linked to the environment in which this study took place.

- This study takes place in the natural world. Most projects referred to by interviewees were commercial and education projects designed and built in Southern California with environmentally conscious features.
- The research study uses multiple methods. Interviews were the main method used during the study, which also benefitted from direct observation and the analysis of documents to a lesser extent by the author in design offices and construction offices, and projects.
- We focus on context. Current literature on the topics of environmentally-conscious buildings and sustainable construction were reviewed and important contextual factors facing the Southern California industry were reviewed to establish perspectives and define context.
- This study is emergent rather than tightly prefigured. A set of interview questions were defined as part of the research protocol approved by SDSU's Institutional Review Board (IRB). However, as the author conducted the interviews and identified new leads relevant to the study, original questions were expanded and refined to capture additional details related to the topic under study.
- The study is fundamentally interpretive. The data presented, interpreted, and analyzed cannot be dissociated from the authors' own experiences and background.

4.1. Interviews

Interviews were deemed to be appropriate to capture perceptions and points of view of professionals involved with the design and construction of sustainable buildings. Interviews are flexible and allow the researcher to explore relevant examples shared by interviewees and pursue relevant lines of inquiry during the conversation [24]. However, to best capture each stakeholder's perspective on cost management, green buildings, and collaboration—the central themes of this research—the research questions were slightly tailored to the expertise of each interviewee. The research was developed in four stages: 1. literature review to elicit principles and practices associated with TVD, 2. approval of research protocol before interviewees were contacted, 3. interview process, and 4. data analysis.

The interviews allowed the first author to collect data about some of the projects referred to by interviewees without directly observing the development of these lengthy and highly interactive processes. However, this format is limited in that the descriptions are biased by the interviewees' own interest and backgrounds and their own recollections of facts [25]. To address these limitations, professionals with different backgrounds, years of experience, and working for different organizations in the industry were contacted. The development of interviews with different professionals had a goal to improve the validity and credibility of the interview process and later its analysis by having the author exposed to distinct narratives associated with different projects.

4.1.1. Interview Subjects

During the interview stage, nine volunteers from the OAEC industry were selected based on personal contacts of the author and the thesis advisor in the local industry (convenience sample). Additional criteria for this population of interviewees was that they should have at least three years of experience in the field of construction, have roles that represented different phases of the D&C process, and exemplify, to the extent possible, different disciplines and roles related to the D&C process. The background and roles of the interviewees at the time of the interviews are summarized in Table 2.

Table 2. Interviewees Profile.

	Project Role	Affiliation	Project Type
1	Project Manager	General Contractor—Construction	Educational, DB *
2	Estimator	General Contractor—Preconstruction	Various, DB *
3	Superintendent	General Contractor—Construction	Museum, DB *
4	Lean Manager	University (Planning)	Educational, on campus
5	Architect #1	Architecture Firm	Educational, CM@risk **
6	Design Manager	Electrical Specialty Contractor	Various
7	Electrical Engineer	Electrical Designer	Various
8	Owner representative	CM	Educational, DB *
9	Architect #2	Architecture Firm	Educational, DB *

* Design-Build (DB), ** Construction Management at Risk (CM@Risk).

4.1.2. Interview Process: Questioning, Recording, and Analysis

During the interviews, the first author used a set of basic interview questions to start conversations about pre-defined topics. A semi-structured interview format allowed interviewees to share relevant aspects about the topics covered by the basic questions, but it also allowed the researcher to ask interviewees to provide additional details to better frame the context of the responses and the technical examples they shared [22]. The interviews were conducted in person or over the phone, recorded with the consent of the interviewees, and transcribed for further analysis.

Each interview was voice recorded with permission granted by interviewees. The purpose of voice recording was to assure that no important information would be missed during the conversation and the actual answers would be preserved. The steps to document the recorded interviews were as follows.

- The voice recording was transcribed and then used to answer the questions asked in the most complete way possible.
- Transcribed answers from the interviewees were revisited in a search for common themes that were later named as "recurrent categories", i.e., themes often brought up by the interviewees. The recurrent categories emerged as either evidence that TVD was already being applied to some extent (e.g., importance of early collaboration, involve building users, encourage owner involvement, etc.) or evidence of the common problems/mistakes observed by the industry (e.g., counter-examples showing the consequences of poor risk management and lack of communication).
- Recurrent categories were identified, listed, and portions of each interview pertaining to specific categories were reported under them.
- Recordings were reproduced with minor writing adjustments in order to eliminate identifiers whenever applicable and to make the language more formal (as opposed to the colloquial speech sometimes captured).
- Quotes reproducing precisely what was said by the interviewees were used whenever the exact narrative/speech/phrase was considered to be of greater impact for the research.

4.2. Limitations

This study is limited to the data collected during interviews, which reflect the views of the interviewees regarding the questions asked. In addition, part of the population interviewed was related to a single project and most of the interviewees had experience in projects related mostly to the education sector. Some of the interviewees had participated in projects outside of Southern California and were able to compare and contrast local practices to those used elsewhere and give examples related to them. Additionally, the study did not quantify costs associated with design and construction of green buildings. The researcher used an analytical process, which compared and contrasted the literature review and interviews to investigate the use of TVD-inspired practices in the local industry in the design of green buildings.

5. Results

The majority of projects described by the interviewees were public educational facilities delivered via Design-Build contracts using a best-value procurement method. Additionally, it is worth noting that state-funded educational facilities in California are required to be at least LEED Silver per Executive Order S-20-04 (2005) [9]. None of the projects referred to during the interviews had used a full-fledged TVD process. However, that does not mean that these types of projects were not available in the geographical area where this study was carried out.

The analysis presented in this paper revolves around two main topics: 1. recurring categories mentioned by multiple interviewees, and 2. TVD-inspired practices used in the design of green buildings. The categories represent contextual factors that define the environment where these professionals work and how they respond to these factors. The practices elicited from the interviews address contextual factors to deliver green building projects in California and were also cross analyzed using the literature review on TVD. The analysis concludes with a list of practices being used, why the practice is important for that task, and how it impacts cost, performance, schedule, and value to the clients.

5.1. Recurring Categories

During the interview phase, interviewees provided support and additional details to major categories identified during the literature review. Rossman and Rallis [23] define a category as "a word or phrase describing some segment of your data that is explicit." The categories presented were identified as recurring topics during the interviews and are discussed in light of their use and relationship to the cost-efficient design of green buildings.

- CA Title 24 and LEED Certification: Business as Usual. The code is part of the routine for the OAEC industry in California and it is almost as strict as meeting Architecture 2030 (another demanding building certification system) [26]. Professionals with specialty areas that are most affected by Title 24 requirements are the ones who get the most amount of training. Moreover, their day-to-day practice helps keep them up to speed regarding strict code demands.
- Motivation for Green Buildings. This study found that the motivation for green buildings in California comes from four main sources: 1. Title 24, especially Part 6—Energy Code, and Part 11—CALGreen [6], 2. mandatory LEED Silver certification for State buildings per EO S-20-04 (2005) [9], 3. owners who want to decrease facilities' operations and maintenance costs, and 4. the Collaborative for High Performance Schools for K-12 schools (CHPS), which advocates the design, construction, and operation of schools to promote student, teacher, and staff success, health, and well-being [27].
- Technology Use. Construction is one of the least digitalized industries and that impacts how buildings are designed, built, and operated. Common software used by interviewees included, but were not limited to, Revit, Bluebeam, Integrated Environmental Solution-VE (IES-VE).
- Cost Modeling. In the design-build projects mentioned during the interviews, the cost modeling started with the following steps: General Contractor (GC) does a conceptual estimating in the pre-bidding phase based on historic data, subcontractor input, and estimating software. Once the owner releases the budget, the GC revisits the cost model and makes the necessary adjustments. The next cost update occurs when the drawings and specs are released. At this point, it is possible to make a more detailed cost model since more information is available.
- Contingency. The main aspects that influence the contingency value as indicated by interviewees were technical issues (e.g., contaminated soil and sites located on a steep hill prone to landslides)

and relationships (e.g., personalities of team members involved with the project and relationships between contractors and suppliers).

- Validation of Business Plan and of the Project Budget. For the design-build projects discussed, the Business Plan validation started in the pre-bidding phase and continued throughout the end of construction. Project budgets would be continuously validated from pre-bidding until 100% construction documents.
- Collaboration: the "trust effect". The impact of trust and quality of relationships on project cost and performance was also observed during this study. Interviewees highlighted that the "trust effect" generated positive outcomes in the following interactions. Specialty contractors provided lower quotes to the GC when they had worked with the GC before and trusted their relationship. Permitting agencies who had established good working relationships with GCs and trusted them would help issue building permits faster.
- Operations and Maintenance (O&M). The following points were observed during the interviews: maintenance staff often resists installation of more innovative energy efficient systems that are difficult to operate and require training. Moreover, although required by Title 24, the demand response is not being leveraged by the market as intended because its intent has been misinterpreted and available equipment might not have features to address this need.

These findings highlight important technical and interpersonal topics that need to be addressed when teams are assembled to cost-effectively deliver green buildings.

5.2. TVD-Inspired Practices Currently Used in the Design of Green Buildings

The following findings collected during the investigation process were identified as cost and performance control practices reportedly implemented by the local OAEC industry. Although the interviewees did not use the term "Target Value Design" to designate the practices and most of them were not even familiar with the "TVD" terminology, this study recognizes the items below as TVD-inspired practices. These are listed in the literature and their effectiveness has been reported in published case studies such as the Sutter Health Medical Center [12] and the St. Olaf Fieldhouse [16]. The contribution of this analysis is to offer practices and examples related to how TVD-inspired principles work in practice during the design of green buildings.

5.2.1. Involve Building Users

Building users need to be involved during the programming process to avoid harmful impacts on the building performance resulting from a lack of O&M knowledge considered during the early stages of the design process. One of the Architects interviewed designed a LEED Silver police station with big garage doors for SWAT tanks in a cold climate where heating loads were important. The energy model showed that the building as designed could save 40% energy compared to the energy baseline. One year after occupancy, the measurement and verification (a LEED credit [8] that was being pursued in that project) showed that large amounts of money were being spent on heating the building. The team later found out that a group of users were rolling up the garage doors while the heating system was on to be able to smoke cigarettes.

In this example, the measurement and verification, which is a very important LEED credit, showed that the building performance was not in accordance with the energy model predictions because the building users were using it differently from what had been anticipated. Had the Architect's team known about the users' habits, they would have designed the building differently. Similarly, had the building users known that their behavior would affect the building performance so much, they could have informed the design team about their habits during the building programming phase (if invited to do so).

The project team learned they must identify the groups of building users and try to learn their habits during the early stages of design. This guideline would address the Transformation-Flow-Value

(TFV) triad given that it would identify the right needs and values of the users and client by preventing loss of value, rework, and backward flows during the design process and the O&M phase.

5.2.2. Promote Transparent Communication

The importance of relationships and trust building is repeatedly stressed throughout this study as a key component for project success. There are lines of communication that are established by the various hierarchical levels in any organization and these lines of communication need to be kept healthy in case issues need to be escalated to upper levels. "Healthy" lines of communication are developed through quality and lasting relationships with people within the organization and across organizations. The examples below explain how transparent communication occurs in practice and supports consistent value generation throughout the project.

- GC and specialty contractors. After receiving the request for proposals (RFPs) from specialty contractors, the GC meets with each one of them to go over every line of the document that defines their scope of work. This happens before parties sign the contract to make sure they are aware of and agree with its terms. The chief superintendent was present in this meeting to discuss schedule, logistics, sequencing, and crew sizes. During construction, a commitment-based planning system can also be used, i.e., the Last Planner System® (LPS®), which is based on public commitment of specific tasks [28].
- Architects and GC. If the Architecture team does not specify the sustainability requirements clearly at the beginning of the project, there is a risk that the GC will not recognize what documentation they are responsible for. That can lead to disagreements down the road, approval of wrong submittals, and delays during construction. According to one of the Architects interviewed, a helpful tool whenever there is a sustainability system being pursued, is to issue an Excel® spreadsheet as part of the specifications. This live document is given to the GC indicating "this specification number is to this LEED credit and this is the format that we need." For instance, if the specification refers to an environmental product declaration, the Architect states: "here's the criteria that the product needs to meet, i.e., the paint: it needs to be 50 g/L of VOC and here's an example of a cut sheet that is formatted the way we need it."
- GC and owner. Part of the DB-team's job to achieve a successful project is to educate the owner about the implications of what they wish to have in their building. For instance, a private owner building a museum in Southern California wanted handmade tiles in the project. Handmade tiles can look nice in isolation or if applied in small scale. However, they do not deliver the same consistent look when compared to a material that is mass-produced. Furthermore, they cost more, take longer to procure, and might not give the client the desired appearance. In this example, the GC provided alternative samples to the customer, explained the consequences of choosing handmade tiles over mass-produced ones, compared the quality of the products, and showed the cost savings of the proposed alternative.
- Maintenance department and designers. When it comes to the acceptance of non-standard building features, maintenance departments were reported to be very challenging to work with. This is understandable because they are responsible for operating the building and, if the project is a green building, they are the ones in charge of keeping it sustainable. However, this group is also the most knowledgeable group to work with since they can tell the project team which systems are actually viable or not in practice.

5.2.3. Design in Small Batches and "Pull" Design

This practice helps the team focus the design effort on priority objectives at the moment by designing in small batches ("pulling the design") so there are no major investments of design time in items that will not benefit the project as a whole. The GC superintendent exemplified that he puts together a schedule with milestones and informs what level of detail they need from each designer at a given project interval. For instance, in order to start grading the site, it is important to know what the foundations and site work are going to be. Therefore, the Architect needs to have the building outline at a minimum and the Structural Engineer needs to know what criteria they will use to start designing the foundation. By doing this, it is possible to get foundation and grading permits in a timely manner. This guideline suggests that design packages are produced to promote flow based on actual project needs and their ability to allow subsequent tasks to start.

5.2.4. Support Timely Action

The guideline is true for items such as processing change orders (CO) and timely decisions that need to be made by the owner, for instance. In a DB environment, there are typically two types of change orders: the ones funded by new money that the owner injects in the project and the ones funded by the project contingency, which is a part of the overall budget. In one of the DB-projects considered in this study, the GC had the incentive of receiving 30% of the remaining contingency at the end of the project. Therefore, it was in the GC's best interest to constantly keep track of change orders in order to not compromise their bonus and the project budget. The importance of timely decisions by the owner is closely related to having a clear project vision, which is explained next. It also supports a smoother flow of tasks to efficiently deliver the project while precisely acknowledging client needs along the way.

5.2.5. Encourage Owner Involvement

Regardless of the contract type, the level of owner involvement in the project has a fundamental impact on the final product (building) and on the team's performance. The owner is the ultimate leader in the project, which means if good decisions are made from the top down, all the stakeholders downstream will benefit from them. An educated and reliable owner makes timely decisions—and stick to them—and sets a clear vision, goals, and expectations, which accurately communicate what they want and that they will not settle for less.

The relationship of the owner with other project team members has to be symbiotic where information flows both ways and at the speed needed by the project. A Lean Manager participating in educational projects in California shared an example of an owner who "camped out" in the big room and stayed there every day facing all the challenges with the construction team. This degree of involvement helps the team deliver the target values defined by the owner who constantly interacts with the team and steers the process towards meeting the project targets.

5.2.6. Define Clear Vision and Goals

Another owner representative leading public educational projects happened to be the campus Architect and had high expectations about the aesthetic, structural performance, and sustainability of the buildings. According to the Lean Manager, in the past ten years, the owner has been responsible for innovative initiatives that included, for instance, implementation of Lean mechanisms in the typical D&C contracts for the projects on campus. These included the use of set-based design in conjunction with CBA, continuous cost estimating, and a TVD dashboard containing all project costs. The early involvement of key stakeholders such as the building users, facilities staff, and security personnel in the design process is also credited to this owner.

According to Ballard and Howell [28], the quality of the final product (output) is just as good as the quality of the work assignments (input). Work assignments are effective when they are: well defined, sound, appropriately sized, in the correct sequence, and evaluated during its execution. By defining a clear vision and project goals, the involved owner supports the effective definition, execution, and flow of tasks that helps advance the project.

5.2.7. Promote Early Planning and Collaboration

The ability to influence positive outcomes is maximized and the cost of changes is minimized when decisions are made early in the project's life cycle [14]. In a collaborative project, the flow from conceptualization through implementation differs significantly from a traditional project. Moving design decisions upstream, as early as possible, to where they are more effective and less costly suggests a rethinking of typical project phases. Examples regarding the impact of early collaboration in different areas are described below.

- Green buildings. Although all project types can benefit from early design decisions, green buildings need to take advantage of synergies between systems to reduce energy and water consumption and promote healthy environments, to name a few.
- Schedule. The more details the GC can get to start building the schedule even before bidding, the less exposed to risks the project will be. This can be accomplished by reaching out to specialty contractors and getting their input on the schedule. The benefits of building a full schedule early on include, but are not limited to, increasing the available knowledge to define the scope of work for each trade, and discovering which trades need to come on board first because of interdependencies with other project tasks.
- Work plan. The early input of experienced and strategic trade partners helps revalidate the GC's work plan and enhance field productivity. The superintendent explained that, as soon as contracts started being executed (in that case for a museum project), the GC started meeting with each one of the trade contractors individually (typically once a week) to get their input, concerns, and mesh that into the work plan. After this process, the GC met with all trades as a group to revisit the work plan before they started doing work. A micro short interval production schedule (SIPS) was developed revealing the planned sequence of work and the efficiencies of the crews for a 1.5-month period.
- Constructability and value to the customer. The more specialized the project, the greater the need for an integrated, collaborative design effort to ensure that the client's needs will be met. In a K-12 school project, the Architect worked with an Electrical Engineer consultant who was very knowledgeable about how teaching stations worked. The Electrical Engineer knew what type of technology teachers needed right next to them and how to lay out elements in a way that they were coordinated with the room furniture and within the teacher's reach.
- Anticipated changes. Professionals in the OAEC industry refer to changes in building projects as the "known-unknowns," which means that some level of change to the original plan will always occur. In a K-12 School project in Southern California, the project team knew that the electric system in an existing campus would need a major overhaul, but they did not know how major that would be until testing could be done. In the end, a large change order came as anticipated but the impact on cost and schedule was mitigated because the team was able to identify the issue early on and plan accordingly.
- Submittals approval expedition. The Electrical Engineer participated in what the project team called a "submittals' party." On a six-story, 250,000 ft. office project, the GC had sent out a comprehensive list of the submittals for the project along with an unusual invitation: all designers, trade partners, suppliers, manufacturer's representatives, and all key project participants who could make decisions about the submittals listed were required to attend to an in-person four-day meeting. The meetings took place in the ballroom of a hotel where the entire project team was staying, and the goal was to approve as many submittals as possible by the end of day four.

According to the Electrical Engineer, there were about seven tables set up in the ballroom with eight people each. The tables were "specialty clusters" representing the disciplines of electrical, architectural, mechanical, plumbing, and more. During this event, a problem was identified for the switchgear submittal: the equipment was too long and it did not fit in its assigned room. Since the manufacturing representatives were attending the same meeting, they could inform the electrical team that, even though the stock section was 30 inches wide, it was possible to make a custom one that was 20 inches wide. They "gained" 10 inches, but it was still not enough, and they had to move a wall. However, there was plumbing behind this wall. Since the architect and the plumbing teams were there, after discussing for 1.5 h, the wall got moved, the plumbing got rearranged, and all the gear fit their assigned space.

The switchgear submittal had originally been issued by the supplier, so they took the updated information at the end of the first day, corrected it by the end of the second day, and submitted the switchgears well as many other submittals that went through a similar process. It was stamped and approved by the end of the third day. The "submittals party" happened only a few weeks after the GC had been awarded the contract and, although a few submittals had to come in later because of the usual sequence of design, a great amount was approved over the course of those four days.

5.2.8. Use of Last Planner System® (LPS®)

The Last Planner System® (LPS®) is a management system, which is part of the Lean Construction Philosophy that helps build a sense of ownership through public commitment [28]. The weekly work plan is called the 'commitment plan' in the LPS®. The foremen of all the specialty trades gather once a week in a field conference room and inform the team which tasks their crews will be accomplishing during that week.

In some of the projects addressed, the teams used a variation of the LPS® original process, which borrows from the pull planning stage in which each trade is assigned a colored sticky note where foremen write down what they are committing to do for the upcoming week(s) and put the sticky note up on a pull-planning board. The public commitment helps hold the trade partners accountable for their promises and also impacts the budgeted costs defined by the involved trade partners during the design process. This practice promotes transparency and information sharing among project participants and aims at promoting a reliable flow of tasks in the project.

5.2.9. Create the Environment: Big Rooms and Co-location

The field of Organizational Behavior recognizes the difference between a manager and an inspiring leader [29]. A manager is simply responsible for the day-to-day achievement while the leader formulates a clear vision that keeps the team motivated and moving forward. Along the same lines, there is a difference between a team and a group. A team generates positive synergy through a coordinated effort while a group might not have positive synergy and is merely a collection of individuals [29]. In the book "Team of Teams," McChrystal et al. [30] discuss the importance of a new type of leader to deal with a world that went from complicated to complex and explains that new leaders need to act more like "gardeners" who cultivate the ecosystem where their team could thrive and make their own decisions rather than simply directing them in a "command-control" fashion.

Accordingly, the concepts of "big room" and co-location cater to the need identified by McChrystal who affirms that good leaders create the environment for their team to thrive and make good decisions. The Owner Representative who has now worked with the same GC in two educational projects co-located in a big room admitted being skeptical and having concerns about working so closely with others in an open office. A couple of years after his first experience, he highlighted the crucial role of the GC's Project Executive in creating an environment that made those working in this environment feel comfortable enough to actually benefit from close collaboration. In this specific case, the co-located team benefited from quicker answers, informal communication, enhanced trust between team members, and other benefits that promoted timely execution of tasks and smoother work flows.

5.2.10. Support Continuous Tracking of Issues and Indicators

Continuous management helps mitigate risks by identifying potential issues early on in the project. Regarding big picture tools, the Project Manager interviewed explained the importance of "key performance indicators" (KPIs) to inform the overall status of the project. The GC monitors KPIs regularly so they can identify issues as soon as possible, define a plan to address them, and get the project back on track.

On a smaller scale, most projects described by the interviewees are benefiting from visual tools such as laminated plans, reports showing the daily goals, and pull-planning boards. Additionally, the Project Manager reported the use of A3s, fishbone diagrams, and the 5 Why's [31] on an organizational scale to share lessons learned about different projects of the same GC. In quarterly meetings, the project team leader would put together A3s showing problems they faced and how they coped with them.

Building on the submittals example presented on Section 5.2.7, the Owner Representative referred to submittals as "silent assassins." The management of submittals is a challenging process because, if they are not approved on time, construction activities and material delivery can be delayed, which affects the project budget and schedule. However, this impact is not obvious [32]. Therefore, the title "silent assassins" given by some practitioners as the management of the submittals can easily get buried in the day-to-day activities of managing a project. Accordingly, the tracking of KPIs and the approval dates of submittals should be analyzed vis-a-vis the project schedule and closely managed to avoid disruptions in the project's budget and work flow.

5.2.11. Validate Budget and Business Plan: Practical Examples that Delivered the Owner Value

Architect #1 compared the value delivered in two different project types they worked on including a pharmaceutical building and a K-12 school. Pharmaceutical buildings require sophisticated and efficient mechanical systems because the equipment they use has high operational costs and dust particles can easily contaminate the drugs produced. Energy efficiency is a primary goal in these cases and it also supports the pursuit of LEED certification. Conversely, in a K-12 school, energy efficiency might not be the number one goal. Instead, the Architect explained that the main goal could be to have a healthy environment for the students by decreasing volatile organic compound (VOC) off-gassing, which is considered within LEED credits.

That said, for green buildings and the LEED certification process specifically, it is important to recognize that not all LEED credits should be treated equally. A good D&C team can guide the owner in the process of continuous budget and business plan validation while finding ways to increase the value with minimum investments.

5.2.12. Manage Risks

Risk management needs to permeate all practices involved in delivering a green building like any other project. A major part of effectively managing project costs is the risk management effort as a whole and understanding what the risks are as early as possible. The following example illustrates the positive impact that pre-planning can have on cost and schedule.

A GC superintendent highlighted the importance of having a site utilization plan, which gives an idea of how the site will look like during the grading phase, the structural phase, the interior build out (including finishings), the site work (hardscape and landscape), and the closeout. Having that helps the GC to buy out the scope of work from trade partners including services that go beyond what is in the plans and specs while considering actual operational needs (and values) of trades building the project. The site development plan somehow addresses work structuring decisions since it considers product and process elements that impact the flow of work on site.

5.3. Summary of Analysis—Guidelines for the Use of the TVD-Inspired Practices

The interviews investigated what the local industry is doing to deliver green buildings in Southern California and which strategies they have in place to steer project costs starting from the design stage. As discussed before, many of these practices are part of, or inspired by, the TVD process. A summary of the interviews is shown in Table 3 alongside an analysis of why each practice is important and how it impacts project cost, performance, schedule, and the value delivered to clients.

Table 3. TVD-inspired practices to deliver environmentally-conscious buildings.

What to Do to Control Cost?	Why Is It Important?	How Does It Impact Cost, Performance, Schedule, and Value?
1. Involve Building Users	- Add more value to the project by better meeting user needs. - Misuse of building systems might lead to severe reduction of performance - Increase building performance.	- Charrette meeting with building users to understand their needs and explain how the building functions.
2. Promote Transparent Communication	- Need to keep "healthy" lines of communication with trade partners, designers, permitting agencies, owner, maintenance department, and general contractor that smooths the process of resolving issues. - Potential impact on approval of submittals.	- GC Superintendent to discuss schedule plan during RFP interviews with specialty contractors. - Architect to create spreadsheet with LEED requirements for GC. - Educate owner on the consequences of their choices. - Get input from O&M department on how building is actually used.
3. Design in Small Batches and "Pull" Design	- Focus the design effort on defining priorities and how valuable they are to advance the project.	- Define a plan indicating what the project needs in terms of what the design and construction deliverables are and when they are needed to promote a continuous flow of work.
4. Support Timely Action	- Avoid the risk of falling behind on schedule and losing track of project cost.	- Use of KPIs. - Quickly handle urgent design matters as they arise.
5. Encourage Owner Involvement	- Owner has great impact on the project's performance.	- Make timely decisions. - Involving key stakeholders early on the design process. - Implementing innovation (contract terms).
6. Define Clear Vision and Goals	- Issues are difficult to resolve if the design intent is unclear, which causes delays.	- Assign an engaged owner representative to oversee the project. - Develop sound assignments.
7. Promote Early Planning and Collaboration	- Enhance constructability. - Optimizing the whole project instead of individual systems. - Anticipate problems before they affect the project. - Help define the scope of work needed from specialty contractors. - Anticipate project needs that go beyond plans & specs. - The sooner green features are defined, the cheaper they will be implemented. - Make rules clear from the beginning so trade partners are not caught by surprise.	- Recognize strategic trades that need special attention. - Build a full schedule even before bidding. - Build a site utilization plan. - Learn about a specialty contractor's work process as much as possible and get their input in the schedule. - Use cross-functional work groups to design building systems. - Anticipate potential change orders to allocate cost and time on the schedule. - Involve trade partners in the planning process early on to avoid scope gaps.
8. Use of Last Planner System® (LPS®)	- Less finger pointing. Avoid "I didn't know/I don't remember" type of situations.	- Ownership through public commitment. During weekly foremen meetings, foremen of each specialty trade write down what they are promising to accomplish on colored sticky notes and put them up on pull planning boards.
9. Create the Environment: Big Room and Co-location	- Motivating people who understand what to do and why they are doing it tend to be more productive. - Open channels of constant communication.	- Use a servant-leader ("gardener") approach as opposed to a command-control approach [30]. Be an inspiring leader instead of a micromanager.

Table 3. *Cont.*

What to Do to Control Cost?	Why Is It Important?	How Does It Impact Cost, Performance, Schedule, and Value?
10. Support Continuous Tracking of Issues and Indicators	- Issues that seem small now can get bigger later and impact the project's performance. - End of project is "crunch time" so there is a tendency to spend more time on general conditions due to management of last minute issues.	- Use visual management tools (LPS® boards/plans, A3, and fishbone diagrams). - Identify root cause of problems using 5 Whys. - Leverage the use of technology (e.g., use of BIM and virtual meetings). - Keep a good and proactive staff to identify and prevent wasteful use of resources.
11. Validate Budget and Business Plan	- Ensure that project goals are being met throughout the D&C process.	- Pursue LEED credits that are compatible with what is valuable for the project.
12. Manage Risks	- Proactive identification of risks throughout the project.	- Discuss alternatives with trade partners. - Communicate unexpected conditions as soon as they are identified/predicted.

6. Conclusions

The study initially reviewed and discussed existing demands placed on the OAEC industry during the design and construction of sustainable buildings in Southern California and their impacts on the delivery of these projects. The delivery of sustainable buildings is usually associated with a perception of high costs supposedly related to green features and materials. However, in places like California, the delivery of environmentally friendly buildings is not a choice, but a requirement defined by the State in its building code, Title 24. In this scenario (discussed in Section 5.1), the use of TVD-inspired practices supports the delivery of these projects considering relevant values stated by OAEC entities from design through O&M while keeping costs under tight control. To support the discussion, a review of the literature on Target Value Design was carried out to identify overarching principles and practices documented and helped in identifying these in actual projects. The practices documented in the literature and summarized in Table 1 are synergistic in nature, which is shown by the number of interactions identified. The practices with the highest number of interactions (4 interactions each) were: work in cross-functional teams, collaborative planning of goals, and capturing lessons learned.

Considering the TVD Benchmark practices presented in Table 1 and the interviews carried out with industry practitioners during the interview phase, a set of practices used in the OAEC industry in Southern California were elicited. Additionally, examples provided by practitioners and the reasoning behind their use are also discussed when appropriate. These practices were summarized in Table 3.

Lastly, a conclusion of the discussion presented in this paper is shown in Table 4, which compares and contrasts data obtained from the interviews (current scenario shown in Table 3) with the TVD benchmark (Table 1). This analysis also reveals existing gaps between theory and practice. The gaps identified point to potential improvements in the design process of green buildings. Table 4 also provides direction to the OAEC industry in terms of what needs to be addressed during training sessions provided to professionals who are part of the process of delivering sustainable buildings. Furthermore, it highlights areas in which further research and case documentation might help advance the knowledge about this topic and its implementation in the OAEC industry.

Table 4. TVD Framework: benchmark vs. current practice.

	TVD Benchmark Practice	TVD Current Practice
A.1	Engage deeply with client	Encourage Owner Involvement
A.2	Keep track of lessons learned (continuous improvement)	Support continuous tracking of issues and indicators (partially observed during the interviews)
A.3	Design to a detail estimate	Not observed during the interviews
A.4	Spend time in planning and do it collaboratively	Promote Early Planning and Collaboration
A.5	Design product and process concurrently	(Partially observed during the interviews)
A.6	"Pull" instead of "push" the design	Design in Small Batches and "Pull" Design
A.8	Work in a big room	Create the Environment: the Big Room and Co-location
A.13	3P (Production Preparation Process)/Mockups	(Not observed during the interviews)
A.15	CBA decision-making	(Not observed during the interviews)
B.1	Timely involve key participants (not too soon, not too late)	Involve Building Users/Support Timely Action
C.1–C.6	Business Plan Development	Validate Budget and Business Plan: Delivering Owner Value
C.8	Clearly set project goals and client's vision	Define clear vision and goals
C.9	Relational contract	(Not observed during the interviews)
C.10	Only client can change scope, quality, cost, and schedule	(Not observed during the interviews)
C.11	Discuss cost, quality, and schedule implications of design alternatives before major investments in design time	(Partially observed during the interviews)
C.12	Continuous estimating	Support continuous tracking of issues and indicators
C.13	Use Last Planner System®	Use of Last Planner System®
C.14	Set a few stretched goals	(Not observed during the interviews)
-	(Not specifically cited in literature)	Promote transparent communication

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