The Thesis committee for Neftali Torres

Certifies that this is the approved version of the following thesis:

Study of Sustainability Opportunities during Construction

APPROVED BY SUPERVISING COMMITTEE:

Supervisor: ______________________________

James T. O'Connor, Supervisor

____

Michael F. Blackhurst

Study of Sustainability Opportunities during Construction

by

Neftali Torres, B.S.C.E.

Thesis

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Dedication

This thesis is dedicated to my mother, Lecy Garcia, who has never failed to give me moral support even during our toughest times. Her inspiration and can do attitude have pushed me to become the person I am today.

I also dedicate this thesis to my family and close friends who have provided encouragement and guidance each step of the way.

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Abstract

Study of Sustainability Opportunities during Construction

by

Neftali Torres, M.S.E

The University of Texas at Austin, 2014

Supervisor: James T. O'Connor

Construction Sustainability involves the processes, decisions, and actions during the construction phase of capital projects that enhance current and future environmental, social, and economic needs while considering project safety, quality, cost, and schedule. Most of the currently available published literature and advances in project level sustainability practices have focused on the early Concept Planning and Design phases of capital projects. Knowledge of sustainability practices during the Construction phase of capital projects is still in the early development stages and is highly fragmented; information regarding the selection, assessment, and implementation of construction sustainability solutions has remained largely unavailable or underdeveloped. Moreover, capital project owners and constructors increasingly seek practical guidance and resources to better integrate and evaluate sustainability decisions and actions within project construction services. The dearth of research on effective sustainability practices during the construction phase suggests that higher levels of sustainability attention and effort are needed in this area, in addition to the creation of support guidance and tools.

To fill this gap in knowledge, this research has identified 54 unique actions that project teams can apply during construction to enhance the overall sustainability of their project. These construction phase sustainability actions (CPSAs) have been cataloged, characterized, and evaluated to facilitate their consideration and implementation by project teams. To further support the selection process and implementation of these actions, the research team developed a high-level strategic work process, a spreadsheet-based CPSA Screening Tool, and additional in-depth guidance for three CPSAs. In addition, both input- and output-oriented construction sustainability metrics have been developed and identified. Equipped with the findings from this study, owners and construction contractors will be better prepared to implement sustainability actions during the construction phase of capital projects.

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Chapter One: Introduction

Problem Statement

For decades, the concept of sustainability and sustainable development has been a topic of growing interest among business organizations, particularly those that are engaged in the planning and execution of capital projects. Studies have confirmed that extensive sustainability programs at the corporate level have been widely adopted and include objectives that are often reported in the Global Reporting Initiative or Sustainable Development Report (Yates, 2008). Most of the currently available published literature and advances in project level sustainability practices have focused on the early Concept Planning and Design phases of capital projects. Despite these milestones, knowledge of sustainability practices during the Construction phase of capital projects is still in the early development stages and is highly fragmented; information regarding the selection, assessment, and implementation of construction sustainability solutions has remained largely unavailable or underdeveloped. Capital project owners and constructors increasingly seek practical guidance and resources to better integrate and evaluate sustainability decisions and actions within project construction services. These major project stakeholders desire enhanced and transparent sustainability decision supports and metrics in order to advance project sustainability culture, engagement, participation, and performance. The dearth of sustainability literature on effective construction phase actions suggests that higher levels of sustainability attention and effort should be targeted during the construction phase of capital projects.

Research Purpose and Objectives

In response, this research focuses on developed structured approaches for implementing and evaluating more sustainable approaches to construction service decisions and activities. The purpose of this study is to provide construction management teams with guidance for determining, implementing, and assessing effective sustainability solutions during the construction phase of capital projects.

The investigation was conducted to better understand the construction management decisions and actions that offer the greatest opportunities for sustainability impacts on projects, to demonstrate the effects of these strategies through applications, and to provide a more quantitative foundation for future decision-making and continuous advancement. The primary intended beneficiaries of this research include contractor and owner managers of capital facility projects and local communities adjacent to construction projects; many suppliers and service providers, such as transportation or waste management service providers, are expected to be indirect beneficiaries. Through this research effort, it is anticipated that owners and construction contractors will be better equipped to implement sustainability actions and respond to sustainability initiatives and expectations. Improving the sustainability of construction services should lead to positive results in the areas of environment, community, and economics; these advances will often promote the enhancement of traditional project performance objectives in safety, quality, cost, and schedule.

Moreover, the primary objective of this study is to determine the most effective practices and associated performance metrics for deploying sustainability-focused initiatives during the construction phase of capital projects. Specific objectives include the following:

(1) Build upon established literature and the foundation previously established by Construction Industry Institute's (CII) Research Team 250, with a focus on construction phase-related elements.
(2) Identify construction decisions and actions that have the potential to significantly enhance sustainability. Place emphasis on identifying and analyzing innovative solutions.
(3) Provide a tool that both project owner and contractor managers can use to identify and screen for high-impact sustainability construction decisions and actions that are most relevant to the project objectives and conditions at hand.

(4) Use demonstration application case studies to validate selected research tools and to gain further insight into their implementation.
(5) Provide a framework for project teams preparing a field operations sustainability plan. Within the framework, recommend sustainability metrics as a basis for benchmarking and key performance indicators.
(6) Identify specific issues for future research.
(7) Through the research products, educate the industry on field sustainability opportunities.

Scope and Limitations

The scope of this research is limited to the construction phase which, in the context of this study, starts when the contractor initiates planning for jobsite presence and ends with the submittal of the final commissioning report. The research scope includes only those construction decisions and actions performed at the discretion of the construction manager (contractor or owner). Examples of construction discretionary decisions and activities that are in the research scope include the design and construction of temporary facilities; means and methods of construction; and management activities associated with the worksite, workforce, subcontractors/suppliers, and temporary facilities. Examples of excluded sustainability actions include those required by either project designs or broad-based regulatory compliance across the construction industry. In addition, actions that only affect safety have been excluded from the scope of this study since CII has employed many research teams focused solely on the advancement of safety.

Organization of the Thesis

This thesis is organized as follows. Chapter 2 presents terminology developed by the research team for the purposes of this study and provides a synopsis of prominent sustainability models and current advances in construction sustainability. Chapter 3 describes the research methodology that was used to conduct surveys, identify construction sustainability practices, develop industry tools, and validate research findings. Chapter 4 describes the Construction Phase Sustainability Actions (CPSA) and CPSA catalog that resulted from this study; an analysis of the characteristics of these CPSAs is also provided. Chapter 5 presents findings from an industry survey that was conducted to evaluate current and future potential implementation levels for each of the CPSAs. Chapter 6 describes the CPSA Screening Tool, which will help project teams screen and prioritize CPSAs prior to formal selection and implementation on projects. Chapter 7 presents an analysis of construction phase sustainability metrics and describes the CPSA Implementation Index Calculator Tool, which will help project teams evaluate construction sustainability implementation effort and progress over time. Chapter 8 discusses the feedback from research validation efforts and follow-on research team reaction. Chapter 9 provides a review of the overall research process and study findings. In Chapter 10, conclusions and recommendations for future research are offered. The appendices contain additional research results and detailed information regarding the construction sustainability process, the CPSA catalog, in-depth methods for examining sustainability issues, and implementation guidance for three selected CPSAs, among other items.

Chapter Two: Terminology and Literature Review

This section defines relevant terminology developed for the purposes of the research and offers a synopsis of available literature pertaining to sustainable development and current advances in construction sustainability. As part of the literature review, background information on sustainable development, common sustainability models, and sustainability drivers and barriers is provided. In addition, CII RT-250's research findings on the implementation of sustainability practices at the corporate- and project-level are highlighted. Finally, advances in project-level sustainability practices are discussed with an emphasis on six focus areas.

Definitions

The research process began with team discussions on the meaning of key terms. The following definitions were developed for the purposes of this research.

- ***Construction Sustainability:*** *the processes, decisions, and actions during the construction phase of capital projects that enhance current and future environmental, social, and economic needs while considering project safety, quality, cost, and schedule.*
- ***Construction Phase:*** *all fabrication/jobsite/field activities and decisions starting with construction/ fabrication contracting and planning for site mobilization through to initial operations, final performance testing, and handover of the completed facility.*
- ***Conventional Project Performance Criteria****: typical criteria for assessing a project's success: safety, quality, cost, and schedule.*

Findings from Literature

Sustainable Development and Sustainable Construction

Throughout its history, the concept of sustainability and sustainable development has been studied extensively by companies and organizations resulting in numerous interpretations and adaptations of the principle. Currently, the most commonly quoted definition of *sustainable development* derives from Brundtland's 1987 report, *Our Common Future*, which defines sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Since this breakthrough definition, sustainability has become a mainstream initiative with continued growing interest.

More recent attempts to define sustainable development discuss additional components that serve to clarify the term. Broader definitions explain that *sustainable development* consists of "social and economic development that protects and enhances the natural environment and social equity" (Diesendorf, 2000) or state that *sustainability* is "a dynamic process which enables all people to realize their potential and to improve their quality of life in ways which simultaneously protect and enhance the Earth's life support systems" (Leadbitter, 2002). Detailed definitions further characterize *sustainable development* as "...a collective responsibility to advance and strengthen the interdependent and mutually reinforcing pillars of sustainable development - economic development, social development, and environmental protection - at the local, national, regional, and global level" (United Nations, 2002). Regardless of how sustainability is defined, all interpretations converge on the fundamental principle that everything needed for survival and well-being depends, either directly or indirectly, on the natural environment (ACRP, 2012). Social, economic, and environmental dimensions must be considered and balanced to adequately preserve our long-term quality of life.

As sustainability was adopted by companies, specialized versions of the concept were developed to incorporate business objectives and interests. In particular, companies that engaged in the planning and execution of capital projects used the term *sustainable construction* to extend these green initiatives to the construction of capital projects. Two common definitions for *sustainable construction* include "creating construction items using best-practice clean and resource efficient techniques, from the extraction of the raw material to the demolition and disposal of its components" (Ofori, 2000) and "practices that have sustainability benefits during the construction phase of a project, including those benefits that may result from decisions made during the planning and design phases of a project" (Peters et al., 2011a).

Common Sustainability Models

As part of these emerging efforts, representative models were developed to further classify and visually portray the concept of sustainability. One such model is the triple bottom line approach which presents sustainability as three overlapping circles acknowledging the interactions between environmental, social, and economic dimensions (shown in Figure 2.1 below). Improvements to these "three pillars" of sustainability are not mutually exclusive and can be mutually reinforcing as illustrated by the overlap of the circles (Adams, 2006). Sustainability is achieved when enhancements in environmental, social, and economic measures converge at the center, where all three circles overlap. Since these circles can be resized to illustrate dominating factors or priorities, this model is often referred to as a weak sustainability model as it implies that the economy can exist independently of the society and environment (Willard, 2010).

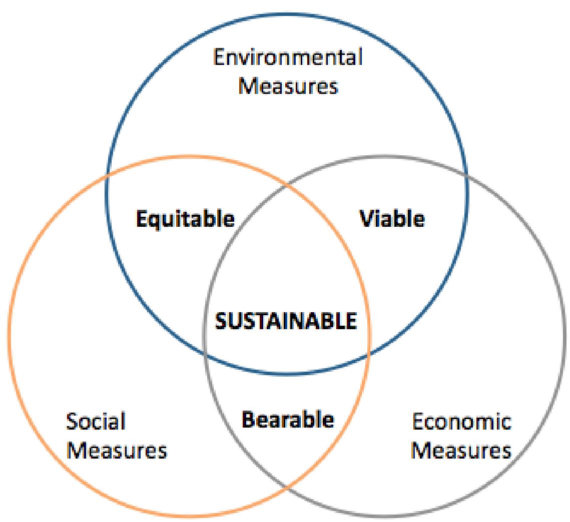


Figure 2.1: Schematic of the Triple Bottom Line Sustainability Model

Since the environment is the ultimate source of resources that power industrial development, many researchers supported the alteration of the triple bottom line approach to nest social and economic systems within the environment, as shown in Figure 2.2. In this "bull's eye" model, the economy operates within social parameters which in turn are embedded within the natural world. This model emphasizes that both the economy and society are constrained by environmental limits (Cato, 2009). A corporation becomes more sustainable as it contracts towards the core because the society and economy utilize fewer environmental resources.

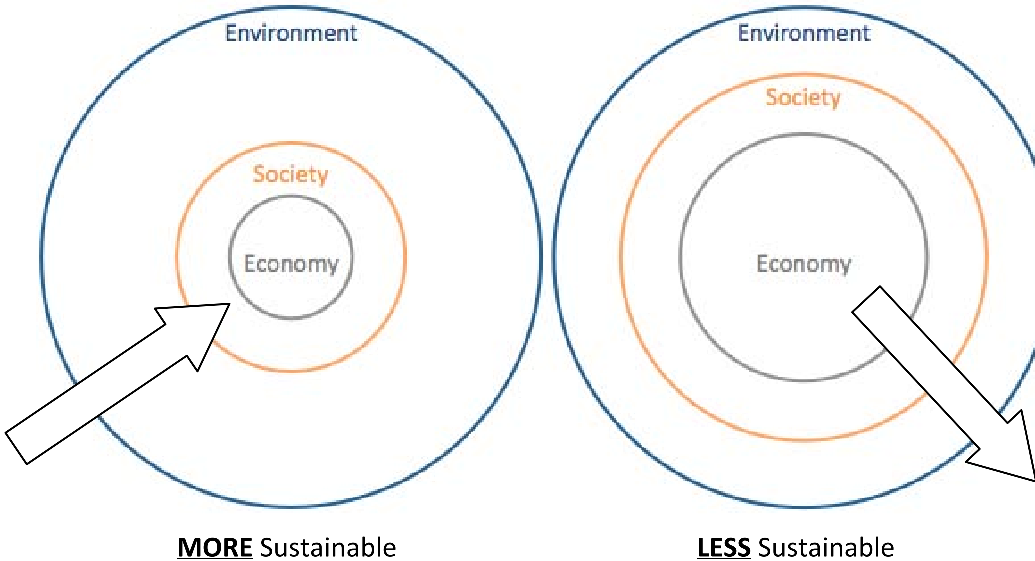


Figure 2.2: Schematic of the "Bull's Eye" Sustainability Model

Another adaptation of the triple bottom line sustainability model is the three legged stool model presented in Figure 2.3 below (Willard, 2010). This representation depicts economic, social, and environmental measures as individual legs that support sustainability. The model reinforces that a balance between the three sustainability parameters must be achieved to adequately support a high quality of life.

Figure 2.3 Three-legged Stool Sustainability Model (Willard, 2010)

While these definitions and rubrics (as well as many others) are insightful and facilitate decision-making, some experts suggest that sustainability is an ideal state that may not be achievable in practice. Thus, a system, change, or decision that moves toward (or away from) that state is considered more (or less) sustainable. Independent of definitions and paradigms, it is recognized that the assessment of sustainability requires the consideration of multiple attributes and simplifications are necessary to make analysis and decisions tractable.

Sustainability Drivers and Barriers

Although sustainability models have their own unique strengths and weaknesses, industry studies have revealed that sustainability drivers and barriers are rooted to more concrete market forces and externalities. In the context of capital projects, the following drivers were found to influence the implementation of sustainability practices (Bekermeyer et al., 2011; CII RT250, 2011; Yates, 2008):

- Owner/stakeholder requirements in design/construction methods and project objectives;
- Government legislation (both national, state and local) and international mandates enacting sustainability policies and standards in the construction of capital projects;
- Saturation in the media and increase in public knowledge and interest of sustainability issues;
- Competitive differentiation and use of sustainability as a marketing strategy (for profit and recruiting purposes);
- Advances in green building technologies and materials; and
- Maintaining quality of life for future generations.

Conversely, these studies have also identified the following prevalent barriers to the adoption of sustainability practices during the construction of capital projects (Berkemeyer et al., 2011; CII RT250, 2011; Yates, 2008):

- Real and perceived higher initial costs;
- Conventional thinking and fear of change with regards to current requirements to complete projects as quickly as possible, achieving a positive rate of return, and remaining competitive within the industry;
- Lack of general knowledge/awareness and insufficient research in sustainable construction;
- Lack of guidelines and precedents for implementation and performance assessment;
- Communication issues between construction trades when attempting to implement sustainable practices across an entire project; and
- Liability concerns, hesitance to implement new products/processes, and uncertainty over profitability (Lindley, 2002).

Corporate-Level and Project-Level Sustainability

Sustainability implementation within business organizations, specifically those that are engaged in the planning and execution of capital projects, can be divided into *corporate-level* and *project-level* sustainability practices (Berkemeyer et al., 2011). Corporate-level sustainability involves broader company efforts to embed sustainability principles into their organizational structure and culture. These companies pursue growth and profitability in addition to goals and performance objectives relevant to societal enhancements and environmental protection as it applies to their sector and business interests. Additional characteristics of these sustainability strategies include the continuous involvement with and learning from national/global green initiatives and public reporting of social and environmental achievements. Studies have confirmed that extensive sustainability programs at the corporate level have been widely adopted by many in the construction industry and include objectives that are often reported in the Global Reporting Initiative and Sustainable Development Report (Yates, 2008).

On the other hand, sustainability at the project level focuses on the practices that are implemented during the construction of capital projects to enforce and realize the targets set by corporate-level sustainability programs. These initiatives target a variety of areas throughout the life cycle of the project, including: construction and demolition waste management, materials selection and management, site energy management and emissions control, indoor air quality, water quality/consumption, and community/social aspects. Evidence suggests that although many companies have a commitment to corporate sustainability, benefits and implementation details at the project level are not well understood (Berkemeyer et al., 2011). Some project-level practices are being employed but performance metrics for benchmarking and improving implementation are often undefined. If more information and guidance on sustainable practices was available, these practices may be applied more frequently on capital projects.

Summary of Advances in Project-Level Sustainability Practices

Most of the currently available published literature and advances in project-level sustainability practices have focused on the early Concept Planning and Design phases of capital projects. Sustainability practices during these early project phases primarily pertain to the selection of sustainable sites; specification of environmentally-friendly building materials (from renewable and recyclable sources, etc.); and evaluation of eco-efficiency optimizations associated with the layout of the permanent facility, building envelope, and integration of HVAC/electrical systems (Pulaski, 2004). Value management processes like designing for construction safety, mechanical predictability/reliability, maintainability, and assembly/disassembly can also be employed to further leverage sustainability benefits (Paramanathan et al., 2004; O'Connor et al., 2003). Studies have estimated that sustainability practices and decisions performed during the conceptual and early design phases account for 60-80% of overall product costs and environmental impacts for capital projects (Libra, 2007).

In response to this lucrative sustainability opportunity, numerous detailed guides and certification systems have been developed to promote the implementation of design and, in some cases, construction practices that enhance project-level sustainability. For example, the U.S. Green Buildings Council (USGBC, 2010) created the Leadership in Energy and Environmental Design (LEED) green building rating system, which is now a nationally recognized benchmark for the design, construction, and operation/maintenance of high performance buildings. This certification effort has resulted in the assembly of a comprehensive collection of sustainability practices (mostly pertaining to the early project phases) that provide insight into the intent, requirements, and potential technologies/strategies associated with project-level application. Similar developments employed by the City of New York Department of Design and Construction (DDC, 1999) and Chicago Department of Aviation (CDA, 2009) have further developed these findings by providing additional information on the objectives, benefits, recommended/best practices, and deliverables for sustainability practices. Case studies and project demonstrations are used to showcase implementation successes.

Despite the dominance of sustainable planning and design initiatives, only a handful of research projects have attempted to identify construction phase sustainability opportunities with various degrees of success. Studies conducted by the Pulaski (2004), the Airport Cooperative Research Program (Peters et al., 2011a), and Venner and Zeimer (2004) have successfully identified a broad spectrum of construction sustainability practices that pertain to surface transportation, reuse and recycling of building materials, project/field logistics, and construction equipment, among other areas. Unfortunately, the breadth (i.e., capturing all possible construction sustainability practices) and depth (i.e., level of characterization of each construction sustainability practice) of information in these collections are inconsistent and, at times, fail to recognize significant factors that influence selection and field implementation decisions made by project teams. Moreover, information on construction practices that significantly influence the community and social parameters of sustainable development is lacking. Knowledge of sustainability practices that can be applied during the construction phase of capital projects is still in early development and highly fragmented. To address these issues, the following sections explore various in-depth studies on specific project-level construction sustainability practices that highlight a number of focus areas including construction and demolition waste management, materials management and materials selection, site energy management and emissions control, indoor air quality, water quality/consumption, and community/social aspects.

Focus on Construction & Demolition Waste Management

Construction and demolition (C&D) waste refers to "waste materials generated by construction activities, such as scrap, damaged or spoiled materials, temporary and expendable construction materials, and aids that are not included in the finished product" (Napier, 2011). Studies conducted by the U.S. Environmental Protection Agency (2012b) estimated that in 1996, approximately 136 million tons of C&D waste was generated in U.S., which accounted for 30-40% of the annual municipal solid waste (MSW) stream; more recent estimates claim that this value may now be closer to 170 million tons annually (U.S. EPA, 2009a). A similar trend has been examined in the UK where 60 million tons of C&D waste are generated annually, more than a third of their total MSW stream (WRAP, 2007a). These wastes consume vast volumes of constrained landfill space and often contain regulated materials which create potential human and environmental hazards. Additionally, landfill tipping fees have substantially increased and will continue to rise as the number of available landfills decline as a result of closures (3D/International, 1999).

Due to the transparency of the issue, sustainable construction practices to improve C&D waste management have been researched extensively and focus on the principles of "reduce, reuse, and recycle." Source reduction of C&D waste can be achieved through tight material quantity estimation and taking more exact measurements in the field to avoid material surplus. Reuse of material involves identifying creative opportunities for utilizing existing onsite wastes as valuable resources. For example, site-excavated material (dirt and gravel) can be used to fill open trenches or act as substitute fill for other earthwork operations (where allowable). C&D waste that cannot be reused onsite can be collected, sorted (on- or off-site), and sent to local recycling facilities.

Many comprehensive guides have been developed to facilitate the adoption of these sustainable C&D waste management practices. Guides developed by 3D/International (1999; 2000) and Napier (2011) provide detailed process steps and strategies for developing and applying C&W waste management plans that far exceed regulatory requirements. The U.S. Army Corps of Engineers (2003) and various other organizations have also developed listings of recyclable construction materials, associated cost data with salvaging these materials, and sample C&D waste management specifications that consider these sustainable practices. Similarly, the Waste & Resources

Action Programme (2007a; 2007b) has developed C&D waste minimization and wastage reduction action plans for the United Kingdom. With comparable land filling and recycling fees, case studies have demonstrated that the implementation of these sustainable C&D Waste Management practices can yield diversion rates of 70-90% with little to no added cost (and in some cases with savings) (3D/International, 1999).

Focus on Materials Management and Materials Selection

Material management practices attempt to further reduce material wastage and improve overall project performance by ensuring efficient material procurement, storage, and handling during construction processes. Sustainable construction practices associated with materials management include the development of material logistic plans (MLPs) that consider lay-down yard sizing/location, traffic management, material delivery policies, and the deployment of automated material tracking systems for warehouse management (Harker et al., 2007). Effective material management systems such as the use of global positioning systems (GPS) and radio-frequency identification (RFID) tags have been shown to reduce the surplus of bulk material from 5-10% to about 1-3% (Bell and Stukhart, 1987); recent studies conducting field trials of automated systems support these results (Nasir et al., 2010). Other potential benefits from the implementation of sustainable material management practices during construction include the improvement of site productivity and the reduction of supervisory time, crew idle time, and damage to stored materials (Nasir et al., 2010). Any unused surplus construction materials can also be resold or donated to non-profit organizations such as Habitat for Humanity's ReStore (3D/International, 1999).

Beyond material specifications that promote the sustainable design of the facility, project teams can consider the selection of sustainability-friendly materials during construction and evaluate different approaches to the pre-fabrication/pre-assembly of construction elements (where contractually allowable). Sustainability-friendly material substitutions emphasize the selection of materials that use resources efficiently (during fabrication), minimize embodied energy/carbon, and avoid products that can harm human or environmental health during the life of the facility (Calkins, 2009). Comprehensive specifications and handbooks are available that detail environmentally-friendly materials and suppliers that provide high recycled content, low-emitting/VOC-free, FSC-certified wood, and rapidly renewable products (Calkins, 2009; Stain et al., 2002). Conversely, pre-fabrication and pre-assembly methods consider issues such as fabrication site location, safety, local employment, reduction of scaffolding, work process productivity, and reduced waste generation. For example, coatings can be applied in a shop environment prior to installation in order to avoid unnecessary exposures and excess material use.

Focus on Construction Site Energy Management and Emissions Reduction

Construction site energy management and emissions reduction/control present a wide variety of opportunities for sustainable development and ultimately involve the reduction of greenhouse gas (GHG) emissions and other air pollutants arising from the combustion of fossil fuels (CO_2, SO_x, NO_x, etc.). Research conducted by the U.S. EPA (2009b) estimated that in 2002, the construction industry in the U.S. generated 131 million metric tons of CO_{2e} emissions which accounted for 6% of total U.S. industrial GHG emissions. An investigation of construction sector emissions in England in 2008 revealed that the highest contributors to construction-related emissions were associated with onsite construction activities (34%) and freight transport (32%) (Ko, 2010). In addition to environmental risks, prolonged human exposure to diesel combustion exhaust from heavy construction equipment and other diesel-fueled equipment has been correlated with reduced lung function, chronic bronchitis, and cardiovascular diseases (MADEP, 2008).

Accordingly, sustainability advancements in site energy management have focused on improvements to construction equipment fleets, the selection of cleaner alternative sources for temporary onsite power and fuels, and optimization of construction operations. With regards to construction equipment fleets, recent developments in fuel-efficient and hybrid technologies for heavy construction equipment will make it possible for contractors to progressively retire existing diesel-powered machines in favor of those fueled by cleaner energy sources. Equipment manufacturers such as Caterpillar have supported this initiative through the deployment of hybrid excavators and loaders that can reduce fuel consumption by 25-30% when compared to their equivalent non-hybrid counterparts, without compromising equipment capabilities or site productivity (Ninmann, 2013; Ninmann, 2012). Moreover, the U.S. EPA's National Clean Diesel Campaign (2013) and the U.S. Department of Energy (U.S. DE, 2013) have provided a wealth of information and resources regarding emissions reduction through the use of diesel-equipment retrofits, idling control technologies, and alternative fuel sources for light- and heavy-duty equipment (ultra-low sulfur diesel, biodiesel, propane, liquefied natural gas, etc.). Early developments in temporary-power generator technologies have also suggested that hybrid diesel generator systems (i.e., a combined diesel generator, battery, and photo-voltaic panel system) and smart-grid/micro-grid technologies may be feasible for off-grid rural applications where the environmental impacts of connecting to grid electricity are relatively high (Kusakana and Vermaak, 2013; Scwerin, 2011).

Strategies for optimizing construction field operations can take the form of many sustainability practices, some of which are discussed here. The deployment of right-sized construction equipment for specific tasks can avoid inefficiencies associated with oversized equipment (safety, mobility, etc.) and provide benefits that include fuel cost savings, reduced operational/maintenance expenses, and less noise and particulate emissions (Ko, 2010). Aside from the use of idling control technologies, equipment idling can be further reduced through improved logistics for material loading/unloading and better coordination between the constructor and supplier to avoid delivery queues. Additionally, the implementation of balanced earthwork strategies can minimize the transportation and placement of excavated soils at off-site locations. More specifically, GPS technologies can be deployed on existing heavy equipment fleets to perform soil volume checks, reduce rework and fuel consumption, and drastically decrease the number of passes for fine grading (Shehata et al. 2012). Evidence supports that the adoption of GPS technologies for earthmoving operations can increase productivity and cost savings by 15-20% over conventional systems (Shehata et al. 2012; Han et al., 2006). Lastly, onsite energy consumption can be reduced through the use of efficient temporary facilities (such as project offices, fabrication shops, storage warehouses, and worker camps) that use computerized system control technologies (such as motion sensors for lights, site lights, site lighting, and HVAC control systems) (Pulaski, 2004; DaintreeNetworks, 2011). Pre-manufactured portable "green" temporary facilities, such as the reMOD trailer, include many of these energy-efficient features and are available for rental (Rubbenstone, 2010).

Focus on Indoor Air Quality during Construction

Indoor air quality practices during construction and just prior to occupancy play an important role in ensuring the long term integrity of HVAC systems, as well as the comfort and health of construction workers and future occupants. Although the costs associated with poor indoor air quality are difficult to quantify, it can lead to illness, decreased occupant productivity, and added costs for equipment operations/maintenance, among other issues (U.S. EPA, 2012a). Consequently, organizations such as the U.S. EPA (2012a) and the Sheet Metal and Air Conditioning Contractors' National Association (Light, 2007) have taken an active role in providing comprehensive guidance for maintaining satisfactory indoor air quality during the construction and renovation of new and occupied facilities; these practices also extend to temporary facilities. Sustainable construction practices associated with indoor air quality focus on controlling air pollutant sources, avoiding contamination of HVAC systems, and interrupting potential contamination pathways. Air pollutant sources typically originate from the contamination of absorptive material such as insulation, carpeting, and ceiling tile. Chemical spills from paints, adhesives, and even water can remain trapped in these materials and cause unpleasant odors and the growth of dangerous molds that can pollute the air for years. In addition, use of permanently installed HVAC units for temporary heating, cooling, and ventilation during construction can further trap dust and other air contaminants and degrade the HVAC system.

Focus on Water Consumption/Quality during Construction

With an increasing population and a rise in water shortages in many regions (in the U.S. and other countries), the need to conserve water is becoming a critical issue (U.S. EPA, 2012c). Moreover, the use of energy resources is linked to water use at all stages of the supply process and by the end user to procure, pump, treat, transport, and store potable water (WBDG Sustainable Committee, 2013; Wayleen et al., 2011). Beyond regulatory requirements for storm water discharges and erosion control, sustainable construction practices in this field incorporate environmentally-friendly methods and technologies that maintain water quality and further reduce potable water consumption. The installation of a screen around the perimeter of the construction site, the use of sweepers equipped with vacuums, and the planting of well adapted vegetation are all examples that can serve as effective dust control measures without the use of water. Treated gray water and storm water that is captured onsite can also be utilized for non-potable needs such as sewage conveyance, vehicle washing, and toilet flushing (ACRP, 2012). Moreover, the installation of designated wash areas with water-efficient tire washing stations with a means for proper re-use and disposal of liquid waste can further improve water quality/consumption and dust control (Veneer and Zeimer, 2004). It should be noted that other sustainable practices, such as regular vehicle inspection and maintenance in a centralized location that can handle/contains fluids, will further prevent and contain the spill of hazardous fluids that could permeate into groundwater systems.

Focus on Community and Social Aspects

During construction, societal factors cover a broad spectrum of opportunities that can significantly influence the performance of a project and have lasting effects on the surrounding communities. Community social responsibility and stakeholder engagement programs allow project teams to respond to stakeholder needs and monitor interests, concerns, and expectations with regard to construction progress and potential issues that may arise (noise, traffic, lighting, etc.) (Chasey and Agrawal, 2012). Local content and Small/Minority/Women Business Enterprise (S/M/WBE) goals for the procurement of materials and services can also benefit the local economy through local tax revenues and job creation, and yield environmental and project enhancements associated with reduced delivery times and fuel consumption (DFW, 2012; Klimley, 1997). Moreover, educational foundations such as the National Center for Construction Education and Research (2011) offer worker training opportunities that support work-preparedness and provide secondary education assistance for local unskilled labor.

International projects typically face additional socials concerns that primarily focus on workforce/worker camp harmony and the employment of expatriates. In order to effectively manage a diverse workforce, project teams must be familiar with cultural compatibilities and should continuously monitor interactions between different cultural communities to create a positive workplace culture that is considerate and responsive to various worker needs (FECCA, 2011). Prior to deployment, expatriates should also receive conflict management, active listening, and sensitivity training to further promote open communication between personnel and improve overall project performance (Jassawalla et al., 2004). In regions that are challenged with a high of local unemployment, the trade-offs between equipment- and labor-intensive approaches should be examined to better understand safety, productivity, local employment, skills training, and other sustainability dimensions. South Africa's Department of Publics Works (CIDP, 2002) and other organizations have extensively studied labor-based methods for employment-intensive construction projects and have created comprehensive best practice guides.

Knowledge Gaps

Recent studies have identified and characterized a variety of construction sustainability opportunities with various degrees of success. Unfortunately, the breadth and depth of information in these collections are inconsistent and, at times, fail to recognize significant factors that influence selection and field implementation decisions made by project teams. A plethora of valuable in-depth investigations and basic tools/checklists on specific construction sustainability practices are available but have remained an untapped resource; information of construction sustainability practices is highly fragmented and is not readily accessible for practical use by project teams. Moreover, guidance regarding the selection, implementation, and assessment of effective sustainability solutions has not been sufficiently developed and is largely unavailable. Further research is required to determine the most effective practices and associated performance metrics for deploying sustainability-focused initiatives during the construction phase of capital projects. If more information and guidance on sustainable practices was available, these practices may be applied more frequently on capital projects.

Chapter Three: Research Methodology

Overview of Process

This chapter provides a comprehensive narrative of the methods employed to deliver the purpose and objectives of this research. Figure 3.1 below presents a summary of the research process performed. Initial efforts focused on developing the purpose and objectives of the research, defining relevant terminology, and planning a research approach. The research team (RT) then reviewed relevant literature and held discussion sessions to identify optional (discretionary) actions that could be implemented during the construction phase of capital projects to enhance sustainability. These construction phase sustainability actions (CPSAs) were further characterized and assembled into a catalog that was sorted by relevant construction functions. A survey was then deployed to evaluate the current and future potential CPSA implementation levels by industry practitioners.

With the completion of the CPSA catalog, the team engaged in the concurrent development of four initiatives: a high-level model of the construction sustainability process, CPSA-specific implementation guidance for three selected CPSAs, a screening tool that would prioritize CPSAs for individual projects, and the creation of a construction sustainability input metric and tabulation of sustainability output metrics. In order to validate the research, drafts of these research products were reviewed by a panel of external experts and industry professionals with experience in construction and sustainability. Revised final work products were prepared in the form of a research summary, three implementation resources, and a research report. Specific tasks and approaches are further described in the following sections.

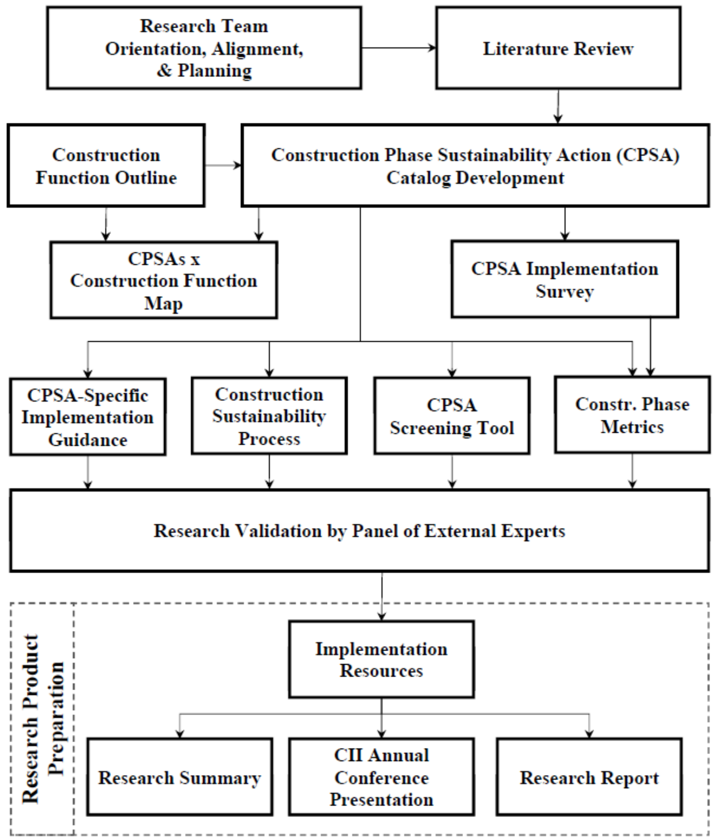


Figure 3.1: Research Methodology Overview

Research Team Background

Initially, a research team member background assessment was conducted to better understand the strengths and experiences offered by the group and identify gaps in knowledge that needed to be supplemented by external experts. Research team members completed a structured three page background survey that collected information regarding project work experience and knowledge of sustainability impacts including: the average size of projects worked on, the percentage of time spent on each project phase, years of experience within each construction sector/sub-sector, and expertise in environmental, community, and economic sustainability drivers. A sample member background assessment template form is included in Appendix A. Survey responses were compiled and processed in spreadsheet format; results were presented in terms of response frequency/counts (out of the 15 research team members) or modified to cumulative years of experience to better reflect the research team's collective body of knowledge. Below is an overview of the survey results:

- RT's cumulative years of relevant industry experience: 316 years
- Mean years of personal industry experience: 21 years
- Organization type (current and previous experience):
    - Owner 47 %
    - Constructor 33 %
    - Design Consultant 33 %
    - Equipment/Material Supplier 13%
    - Other* 40%

* Included roles in research, academia, subcontracting, and independent consulting.

- Average project size (current and previous experience):
    - <$10 mill 40 %
    - $10 mill to $50 mill 33 %
    - $50 mill to $200 mill 27 %
    - $200 mill to $500 mill 47 %
    - > $500 mill 40%
- RT's cumulative years of experience by project phase:
    - Feasibility/FEED 25 %
    - Detailed Design 17 %
    - Construction 43 %
    - Commissioning/Operations 15 %
- RT's cumulative years of experience by primary sectors of capital projects:
    - Industrial 62 %
    - Infrastructure 23 %
    - Commercial/Buildings 15 %

Figure 3.2 below examines the research team's years of experience by construction sub-sector. It was found that within the industrial sector, the team's experience in power generation, petro-chemical, and metals manufacturing projects was 49% of the cumulative years (147 years out of 316 years). Moreover, 20% of the cumulative years were attributed to underground utility, roads, and ports/marine projects within the infrastructure sector. Only 12% of the team's cumulative experience was in office building, retail/shopping, and school/university projects within the commercial sector.

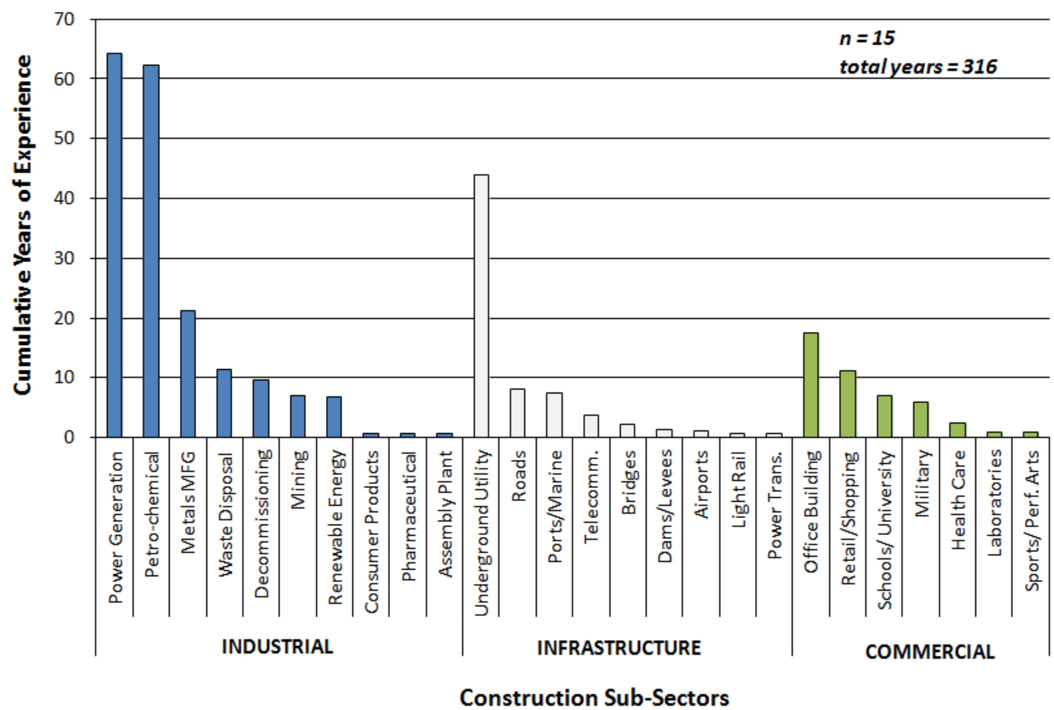


Figure 3.2: RT's Cumulative Years of Experience by Construction Sector

The research team's cumulative years of experience by various project characteristics was also analyzed and is shown below in Figure 3.3. The results indicate that the research team was more familiar with U.S. domestic projects (67% of cumulative years), projects within the private sector (62%), and working on projects near developed locations (85%). Project experiences within rural/urban, Greenfield/Brownfield, and open shop/union settings and conditions were nearly evenly distributed (≈ 45-55%).

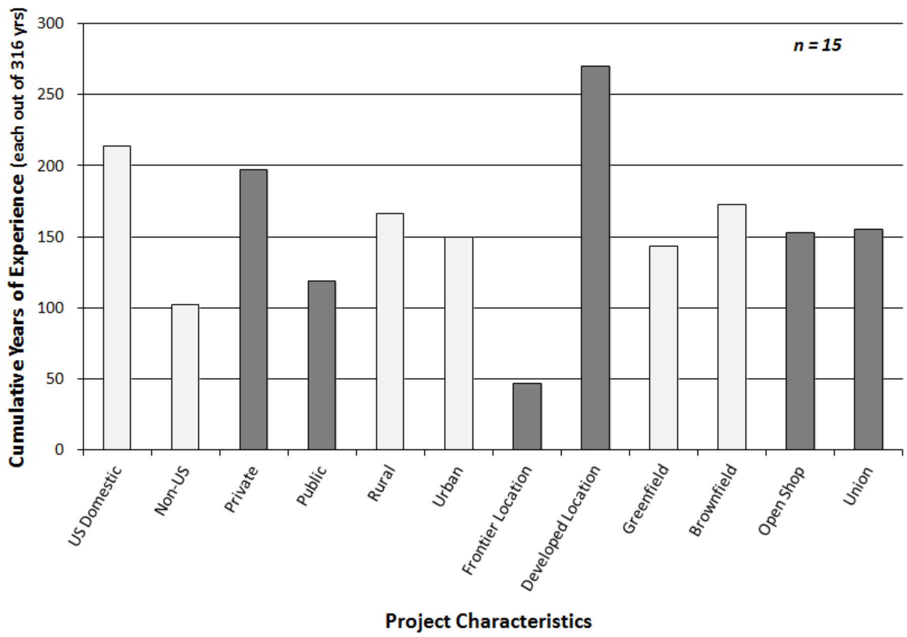


Figure 3.3: RT's Years of Experience by Project Characteristics

The research team's collective knowledge on sustainability impacts and drivers is presented in Figure 3.4 below. Survey response counts for this section were grouped into members with advanced knowledge and members who were recognized as designated experts in the specific area. With regard to environmental impacts, the team was most familiar with energy use, waste management, and material consumption. As for social impacts, the team had the most experience with construction safety, safe working environments, and workforce training. As for economic impacts, the team was most knowledgeable in net economic impacts, demand on local resources, and in-kind contributions.

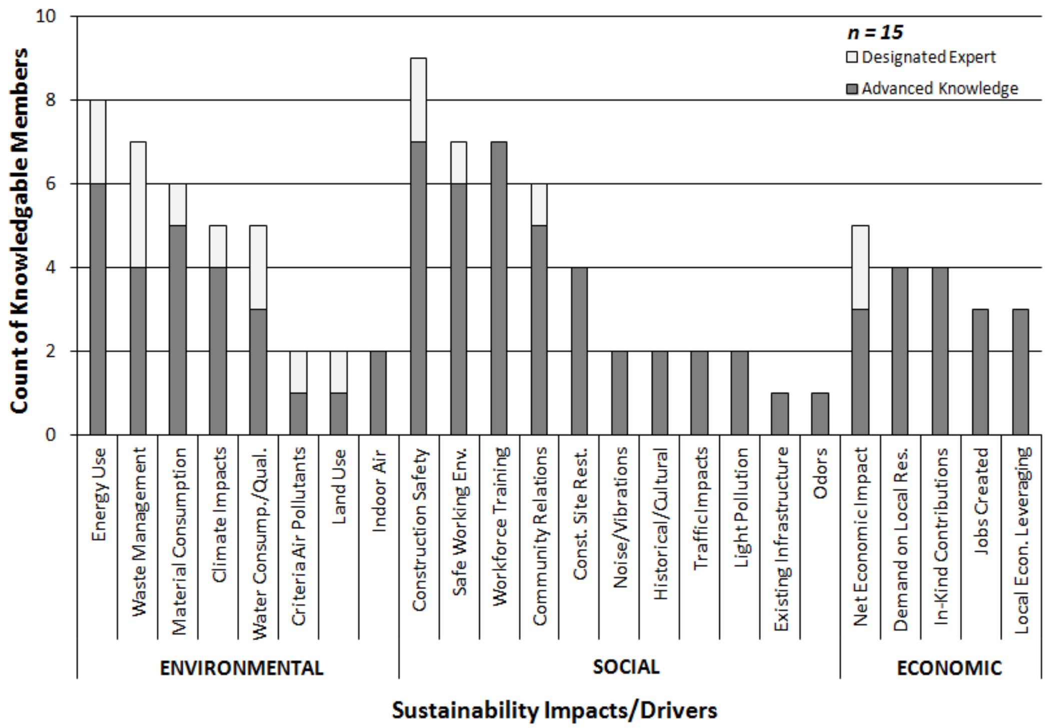


Figure 3.4. RT's Knowledge on Sustainability Impacts/Drivers

Research Team Orientation, Alignment, and Planning

Orientation sessions and research workshops were periodically conducted to familiarize the team with the topic of sustainability and develop a focused purpose and objectives for the study. Group discussions resulted in the classification of key terms that would be utilized throughout research. The meaning of terms such as *construction sustainability*, *construction phase*, and *conventional project performance criteria* were initially extracted from existing publications, which included both CII and non-CII sources, and further refined by the team based on their industry experience; definitions are presented in Chapter 2 of this report. Clarifying these terms at the onset of the study further aligned the research team and avoided confusion throughout the rest of the investigation. Team orientation, alignment, and planning also led to the development of the research approach described in this chapter.

Literature Review

As part of this investigation, a review of relevant literature was conducted to better understand prevailing sustainability models and current advances in construction sustainability. Completed and ongoing research projects that addressed the topic of sustainability were located and analyzed to determine their applicability to construction projects. Information was collected from the United States and foreign countries; sources included "green" initiatives supported by government agencies/departments, relevant industry publications (journal articles, conference papers, research reports from engineering and construction societies, etc.), presentations on sustainability and sustainable development, product white papers, magazine articles, and discussions with sustainability experts and other industry specialists. Only information that was presented in English or translated into English was considered. Findings and gaps in knowledge are discussed in Chapter 2 of this report. The literature review was divided into specific focus areas to cover aspects of sustainability that would assist the research team in better defining the purpose, objectives, and scope of the study and provide guidance on further research tasks. These focus areas are as follows:

- Prevalent sustainability models and their associated terminology, components, drivers, and barriers.
- Literature review findings established by CII RT-250, with an emphasis on corporate- and project-level sustainability.
- Advancements in project-level sustainability including the investigation of existing effective construction practices and solutions that enhance project sustainability performance.

Construction Phase Sustainability Actions

Research efforts then focused on the identification of optional (discretionary) actions that could be implemented during the field construction phase of capital projects to enhance sustainability. These construction phase sustainability actions (CPSAs) were comprised of effective practices, strategies, and decisions that offered sustainability benefits within environmental, social and, in some cases, economic impacts. Preliminary CPSAs were conceived from many of the cited sources in the literature review that described existing and proposed construction sustainability practices. This endeavor was supplemented by conducting numerous individual and research team brainstorming sessions to gather insight on accepted contractor/owner sustainability practices and developments, discussions with subject matter experts, and participation in conferences and small outreach panels to extract information from other industry professionals. A spreadsheet database was utilized to compile CPSAs and record/maintain information such as: the CPSA's working title and description, source citations, approval status, estimated sustainability impacts, and number of reviews by the research team.

Once a draft title and brief narrative were developed for a new CPSA, the estimated sustainability impacts that would be realized from its implementation were assessed through research team deliberations. A sustainability impact rating model was developed that consisted of five levels to facilitate preliminary classification of the CPSA's sustainability impact magnitude within specific environmental, social, and economic parameters. A description of this model is presented below:

- A rating of "+" suggests that the implementation of the CPSA will have a positive influence on the respective primary impacts.
- A rating of "-" indicates that the implementation of the CPSA will likely have a negative influence on the respective primary impacts.
- A rating of "+ +" or "- -" was used to place emphasis on CPSAs with significant positive or negative influences on the respective primary impacts.
- A rating of "N" signifies that respective primary impacts are minimal or negligible.

The original sustainability impact rating model also contained a "U" rating for CPSAs whose primary impacts were unknown or could result in either positive or negative impacts based on project conditions and other factors; CPSAs with this rating were further investigated and discussed until the research team agreed on one of the other five sustainability ratings. In some cases, CPSA descriptions were modified to emphasize these favorable conditions or exceptions.

As new CPSAs were identified, an extensive review and approval process was conducted to ensure that CPSAs were consistent in quality and aligned with the scope of the research. CPSAs were assigned a status of "new", "approved", or "rejected" based on the number of reviews and overall consent by the research team; the CPSA spreadsheet database was used to continually update and sort CPSAs by approval status. CPSAs underwent multiple reviews to refine their working titles, descriptions, and estimated sustainability impacts. Grounds for the rejection of new CPSAs were primarily due to the following out of scope items:

- The CPSA was unclear or vague;
- The CPSA was redundant or was merged with another existing CPSA;
- The CPSA had negative environmental or social sustainability impacts;
- The CPSA had minimal positive or negligible impacts across all primary sustainability impacts;
- The CPSA had only positive economic impacts;
- The CPSA was not a discretionary action and was required by design and broad-based regulatory compliance/policy;
- The CPSA would typically be implemented outside of the construction phase.

A secondary review of all approved and rejected CPSAs was performed as a quality control measure before finalizing the list of accepted CPSAs. This effort resulted in the identification of 54 CPSAs. The research process for the supplementary characterization of each CPSA is discussed in the following section.

CPSA Catalog

Structure of the Catalog

A template entry form for a CPSA catalog that would allow detailed characterization of individual CPSAs was developed concurrently with the identification of CPSAs. Through an iterative process, the template entry form was reduced to a one page document that featured the most important content regarding the specific CPSA. Limiting the document to one page per CPSA made the catalog more manageable and accessible to project teams who would be interested in learning general information about a CPSA before deciding to implement it and/or pursue in-depth examinations. Each catalog entry describes individual CPSAs with the following information:

- Number and title of the CPSA;
- Primary and secondary construction functions associated with the CPSA;
- Description of the CPSA;
- Estimated sustainability impacts from CPSA implementation;
- Estimated influence of the CPSA on conventional project performance criteria;
- Estimated ease of CPSA accomplishment or implementation;
- Project conditions that leverage benefits from the CPSA;
- Sustainability performance output metrics;
- Common barriers to successful implementation of the CPSA;
- References, for more information on the CPSA.

A sample CPSA catalog entry template form is included in Appendix B. The following sections detail the development and completion of specific fields within the catalog entry form. Catalog information was collected and processed in spreadsheet format to permit analysis on collective characteristics of all of the CPSAs. Results from this exercise are presented in Chapter 4 of this report; this is with the exception of findings for the sustainability output metrics field (field "G"), which are discussed in Chapter 7 of this report. The full version of the CPSA catalog is included in Appendix C.

Construction Functions

CPSAs were assigned to specific construction functions to provide better insight into where the CPSAs fit within the construction process; this exercise also allowed the team to evaluate the distribution of CPSAs across these construction functions and highlight areas that required further attention.

The development of construction functions was an iterative process that began with the assembly of a comprehensive listing of construction functions based on the research team's industry experience; this register was further refined through external expert reviews. Through this exercise, an inventory of 18 primary construction functions was generated along with 81 sub-functions that served to further complement and define the primary functions. As CPSAs were identified, the relevant construction functions were assigned through research team discussions (located in field "A" of the CPSA catalog). CPSAs were then sorted by these construction functions to discern functions that had insufficient CPSAs and required further attention. These missing gaps were often the primary focus for lightning brainstorming sessions to conceptualize new CPSAs.

As the register of accepted CPSAs was finalized, construction functions were consolidated into broader categories to better organize CPSAs. The final list of construction functions was reduced to the following eight primary functions:

- Project Management;
- Contracting;
- Field Engineering;
- Site Facilities & Operations;
- Craft Labor Management;
- Materials Management;
- Construction Equipment Management;
- Quality Management, Commissioning, & Handover.

Sub-functions were removed from the list as they were no longer required for function characterization purposes. Additionally, assigning sub-functions to CPSAs would have been a cumbersome endeavor that added little value to the study. If warranted, a second primary function was assigned to CPSAs that were relevant to more than one construction function.

Impacts on Sustainability

As previously discussed, the CPSA identification process featured the preliminary classification of estimated sustainability impact magnitude for environmental, social, and economic impacts through a five level rating system. These estimated impacts were further characterized by determining the most affected areas and resources within each primary sustainability impact. Sustainability impact areas were assessed within the context of construction projects.

A listing of potential impact areas and resources was generated from the literature used to identify CPSAs and research team brainstorming sessions. These impact areas were then assigned to environmental, social, and economic dimensions. In some instances, impact areas that are traditionally associated with specific primary impacts were assigned to other primary impacts that better corresponded with the nature of capital projects. For example, impact areas such as tax revenue produced, local resource depletion, and jobs created were viewed as social impacts, rather than economic impacts, since the local community would directly experience these benefits. Within the context of capital projects, it was determined that economic impacts would be associated with direct and indirect project costs and savings associated with CPSA implementation. Final sustainability impact areas were consolidated into the following groups and presented as pull-down menu options within field "C" of the CPSA catalog to support the analysis:

- **Environmental:** energy consumption, greenhouse gases, criteria air pollutants, indoor air quality, water consumption, water quality, waste generation, land use, noise pollution, odors, light pollution, or negligible

- **Social:** health and safety, skills development, community relationships, local resource depletion, community infrastructure, traffic, jobs created, tax revenue produced, community service donations, or negligible
- **Economic:** project fiscal impacts, or negligible

CPSAs were then assigned the most prominent impact areas that would be affected by CPSA implementation (maximum of three areas). As part of this endeavor, sustainability impact magnitudes were further refined to reflect the research team's enhanced interpretation of construction sustainability.

Impacts on Conventional Project Performance Criteria

Each CPSA's influence on conventional project performance criteria was also assessed (field "D" of the CPSA catalog). These measures for project success typically focus on safety, quality, cost, and schedule objectives. Only positive impacts were recorded in the catalog since CPSAs with significant negative influences in any of these objectives would compromise the success of the project; these CPSAs were regarded as unsustainable and were moved to the rejected CPSA group.

Ease of Accomplishment/Implementation

Additionally, the research team evaluated the level of difficulty that should be expected when attempting to implement individual CPSAs. Ratings of "easy", "moderate", and "challenging" were assigned to CPSAs based on the effort required to properly incorporate a CPSA into existing project execution processes. Some of the factors that were considered during this evaluation included: resource requirements, out-of-pocket expenses, demand for skill or experience, amount of implementation effort/time required, and leadership effort required to initiate process change.

Project Conditions that Leverage Benefits

Project conditions that leverage benefits from implementation of the CPSA are one of the major components that can help project teams prioritize and select CPSAs for implementation based on their project-specific characteristics. Through literature review and research team discussions, the most prominent/favorable project conditions were identified for each CPSA (field "F" of the CPSA catalog). During these sessions, four to five favorable project conditions were determined for each CPSA. These entries were narrowed down to the three most prevalent conditions for each CPSA and recorded in the free-form textboxes in field "F" of the CPSA catalog. The leveraging project conditions were also recorded in a spreadsheet to allow further analysis of the collection. These leveraging conditions were then grouped and sorted into the following seventeen categories that were associated with project characteristics and the project execution process:

- Objectives & Priority;
- Benchmarking;
- Project Scope;
- Project Site;
- Stakeholder & Community Relations;
- Project Contract;
- Procurement;
- Project Organization;
- Project Communications;
- Health, Safety, Environment;
- Logistics;
- Temporary Facilities;
- On-Site Temporary Power;
- Construction & Demolition Waste;
- Craft Labor;

- Construction Equipment;
- Commissioning.

A review of the sorted collection of leveraging conditions revealed that many of the CPSAs had very similar leveraging project conditions; these project conditions were further consolidated to provide more consistent quality and expression in the collection. Edits that resulted from the consolidation effort were also updated in the CPSA catalog entries. This consistency in wording was essential since these leveraging project conditions would be utilized later in the study as one of the primary building blocks and user inputs for the CPSA screening tool.

Sustainability Performance Output Metrics

Sustainability performance output metrics were also evaluated for each CPSA. These metrics can be used by project teams to measure actual achievement of one or more specific performance goals during CPSA implementation. With a plethora of possible output metrics for each CPSA, it was decided that an approach similar to the one performed when generating project leveraging conditions should be applied. Through literature review and research team discussions, the most prominent (and practical) output metrics were identified for each CPSA (field "G" of the CPSA catalog). During these sessions, the research team attempted to identify as many output metrics as practical given time constraints. These entries were narrowed down to the two most practical metrics for each CPSA and recorded in the free-form textboxes in field "G" of the CPSA catalog. Findings were also documented in a spreadsheet to permit further examination of the collection. The listing of metrics was then grouped and sorted into the following nine categories associated with the performance measure:

- Benchmarking;
- Contracting and Procurement;
- Work Processes;
- Construction & Demolition Waste;

- Labor & Staff;
- Equipment;
- Facility Commissioning;
- Environmental Footprint;
- Community or User Satisfaction;

Output metrics that were very similar were further consolidated to provide more consistent quality and expression. Any changes that were performed during this exercise were also applied to the CPSA catalog entries.

Barriers to CPSA Implementation

Barriers to successful CPSA implementation were investigated to provide additional insight into some of the issues that may be encountered when incorporating a CPSA into existing project execution processes. Identifying some of the more prevalent roadblocks for each CPSA will increase a project team's awareness/expectations and help them better prepare the necessary contingencies to overcome these potential obstacles. Through literature review and team discussions, the most significant barriers were identified for each CPSA (field "H" of the CPSA catalog). During these sessions, three to four barriers were identified for each CPSA. These barriers were then narrowed down to the two most significant barriers for each CPSA and recorded in the free-form textboxes in field "H" of the CPSA catalog. Barriers were also compiled in a spreadsheet for further analysis of the collection. The listing of barriers was grouped and sorted into the five categories presented below; descriptions for each of the categories are provided for additional clarification:

- **Lack of information:** Unawareness or inexperience from the project team (both contractor and owner) can be attributed to a lack of information needed to properly assess requirements for successful CPSA implementation. Barriers related to uncertainties/risks were also assigned to this group since uncertainties decline as information becomes available.

- **<u>Limited project resources:</u>** Project resources including equipment, labor, time, and overall funding are typically allocated based on project objectives and priority. Even if benefits of CPSAs are known, resources are often constrained and may not be able to support the implementation of a specific CPSA.
- **<u>Outside owner/contractor control:</u>** Several CPSAs require coordination of stakeholders outside of the project teams (owner and contractor). Some stakeholders may perform decisions that impact the project's ability to successfully implement a CPSA. Additionally, some suppliers may not be willing to participate in sustainability initiatives which further hinders implementation attempts.
- **<u>Lack of infrastructure:</u>** This category was assigned to barriers that dealt with the availability of materials, equipment, and/or facilities and services outside of those required by the project.
- **<u>Unfavorable site or project conditions:</u>** Regulatory or regional issues were grouped into this category.

Detailed barriers for each CPSA were not consolidated since most of the issues were CPSA-specific.

CPSA Implementation Survey

Survey Structure and Data Gathering Approach

Once the CPSA catalog was finalized, an industry survey was conducted to better understand current and future likely levels of CPSA implementation within the construction sector. Investigating CPSA implementation will also provide insight into how the industry perceives these CPSAs and help establish a benchmark for CPSA application. The survey was distributed to both CII Research Team 304 members and qualified industry practitioners selected by the research team. Qualified participants included external CII-members and non-member engineering and construction professionals that were designated experts in sustainable development initiatives who were familiar with construction practices within their company. Examples of qualified participants included field engineers, project/construction managers, HSE (health, safety, and environment) personnel, and sustainability specialists/managers.

The survey was organized into two sections. The first section requested general background information from the participants including their number of years of industry experience, project roles, the primary sector of capital projects they have worked on, and company size by employee count. Company and participant names were not collected in order preserve the anonymity of the survey; but respondents had the option to provide their contact information if they wished to participate in follow-on studies; this contact information was not used during the survey response analysis. The second section inquired the respondents' answers to two-multiple choice questions, presented below, for each of the 54 CPSAs; the questionnaire included the title and description of the CPSA, along with check boxes for answers and textboxes if written clarification of the selected answers was required.

Question 1. For CPSA #X described above, how frequently have your project teams applied this action on projects over the last few years?

a) CPSA has never been applicable

b) Never, but CPSA has been applicable

c) Rarely

d) Sometimes

e) Frequently

f) Don't know; I need more information

Question 2. For CPSA #X described above, how likely would your team implement this action on future projects?

a) Not likely

b) Somewhat likely

c) Very likely

d) Don't know; I need more information

The survey was constructed in Excel and distributed with an introductory email describing the purpose of the survey and completion/submission instructions; responses were collected in spreadsheet format for further analysis. Background information from the first section of the survey was used for collective characterization of survey respondents while answers from the second section were processed and plotted on a matrix of current application of the CPSA by potential future application of the CPSA. The research team developed a scoring model to permit the collective processing of responses from the second section of the survey.

For the first question, responses were scored as follows:

- 0.00 points if the "never, but CPSA has been applicable" answer was selected;
- 0.33 points if the "rarely" answer was selected;
- 0.67 points if the "sometimes" answer was selected;
- 1.00 points if the "frequently" answer was selected;

For the second question, responses were scored as follows:

- 0.20 points if the "not likely" answer was selected;
- 0.60 points if the "somewhat likely" answer was selected;
- 1.00 points if the "very likely" answer was selected;

It was determined that if the "don't know; I need more information" option was selected for either question, a score would not be assigned and the response would be excluded from the analysis. The sum and averages of the score for each CPSA were computed and plotted in a current versus future CPSA application matrix. Matrix boundaries between survey response options were delineated evenly based on the scoring models presented above. Survey findings are presented and discussed in Chapter 5 of this report.

Study Participants

In total, 33 participants completed substantial portions if not all sections of the survey. As this is not a large random sample assured to be representative of the industry, it is important to understand the characteristics of the survey respondents. These characteristics include the following:

- Median years of personal industry experience: 26+ years
- Organization type:
    - Contractor 70 %
    - Owner 27 %
    - Supplier 3 %
- Primary sector of capital projects worked on:
    - Industrial 55%
    - Commercial/Building 33 %
    - Infrastructure 12 %
- CII member company:
    - Yes 82 %
    - No 18 %
- CII RT-304 member:
    - Yes 27 %
    - No 73 %
- Current job title:
    - Construction/Project Manager 39 %
    - Department Manager/Director 32 %

- Sustainability Specialist 16 %
- Other* 13 %

* Included project engineers, field engineers, and project controls personnel, among others.

- Median size of company by employee count: 2,000 - 10,000

CPSA Screening Tool

Development Approach

At first glance, a catalog of 54 CPSAs may pose a challenge to project teams seeking to select and implement a limited number of CPSAs for their project. In response to this concern, a tool was developed to provide a means for screening and prioritizing the collection of CPSAs for implementation on projects; the CPSA screening tool was designed to assist project managers in determining good-fit CPSAs that are more applicable for their project. Development phases for the tool consisted of conceptualization, detailed planning, tool programming, and internal testing and debugging.

The conceptualization stage of the tool focused on determining the appropriate screening tool inputs, outputs, logic, and computational mechanics. During a kick-off discussion, it was determined that the approach to screening should be project-oriented rather than user-oriented to better promote the implementation of relevant CPSAs on construction projects. Accordingly, the inputs used to screen CPSAs would be project-specific sustainability priorities and project-specific characteristics. These inputs were the most favorable since the sustainability impact and leveraging project condition fields within the CPSA catalog could be used as comparative data to assess the compatibility of a CPSA (fields "C" and "F" of the catalog, respectively). It was decided that the primary output for the screening tool would be a prioritized-ranked listing of the CPSAs based on the computation of a Relevance Index (RI), a composite numerical score that would measure the applicability of a CPSA to the user's inputs. Using these building blocks, the research team developed the screening tool logic flowchart shown in Figure 3.5 below. In general, user inputs would be collected in the form of affirmative yes/no responses (which are converted to values of 1 and 0) and numerical inputs that would be compared to resident fixed databases within the tool. Interim and final scores would be computed to allow the ranking and sorting of CPSAs. Based on this logic and the research team's programming experience, it was determined that Excel was an appropriate platform for tool programming and would be familiar software to construction industry practitioners who would be the primary users of the tool.

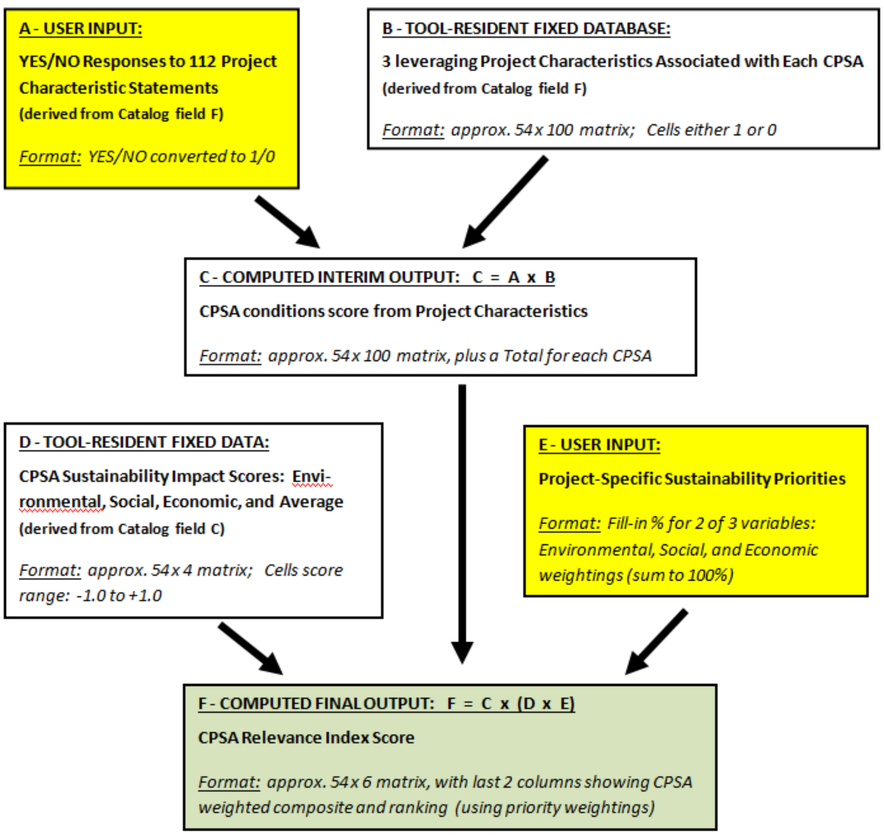


Figure 3.5: CPSA Screening Tool Logic Flowchart

The detailed planning phase consisted of further outlining the architecture and structure of the screening tool in a manner that would facilitate user interactions and leverage Excel's functions and capabilities. It was determined that the Excel-based screening tool would contain two types of tabs: resident databases and interface tabs. Resident databases contain fixed data and perform the RI computations; these databases are viewable or accessible to the user. The screening tool features three resident databases. The primary CPSA database contains the majority of the raw fixed data extracted from relevant CPSA catalog entry fields and performs RI computations; this database serves as the central hub where all of the user inputs, recorded in other tabs throughout the workbook, are interpreted. The second resident database is the leveraging conditions database which contains fixed data from the leveraging project conditions field in the CPSA catalog (field "F") and record the user inputs for project-specific characteristics. The third resident database is the rules and scoring model database which contains raw fixed data from scoring models established by the research team and records the user inputs for project-specific sustainability priorities.

The interface tabs are viewable to the user and are utilized to collect user inputs and present final screening results. The screening tool features five interface tabs. The first two interface tabs provide introductory information and general guidance on the use and function of the screening tool. The third and fourth interface tabs prompt the user to enter values for their project-specific sustainability objective priorities and mark/check applicable project characteristics from a list of statements/questions (extracted from CPSA catalog field "F"). The last interface tab interacts with the primary CPSA database and displays the final prioritized listing of CPSAs from highest to lowest RI; other relevant information such as the CPSA title, description, and leveraging project conditions are presented in tabular format.

Once detailed specifications and requirements for the CPSA screening tool were defined, the team proceeded with the programming of the tool. Relevant information was extracted from the CPSA catalog entries and compiled into spreadsheet matrix format; computational mechanics and scoring models were then programmed into the resident databases. Lastly, interface tabs were developed and additional features were created including: "back" and "next" buttons to navigate between user interfaces, pop-up messages to provide supplementary instructional guidance, and other visual aids.

Upon completion of tool programming, the prototype screening tool was distributed to the research team for internal testing and debugging. This review phase was performed as a quality control assessment to evaluate the clarity of the information and instructions presented and ensure proper tool functionality and scoring computations; grammatical errors and other relevant concerns were also identified. The screening tool was modified to address all research team comments. Additional information regarding the final CPSA screening tool mechanics including inputs, outputs, computation assumptions, and algorithms are discussed in Chapter 6 of this report.

Project Demonstrations/Applications

Upon completion of the CPSA screening tool, the research team sought to further verify the functionality and applicability of the tool through demonstrations on real world construction projects. More specifically, the research team was interested in performing trial applications of the screening tool on capital projects that were in the front-end planning and early execution phases to evaluate how potential CPSA implementation would be conducted within representative projects in the construction industry.

The project demonstrations consisted of a preparation/debriefing call, application of the CPSA screening tool, and a debriefing interview. A one-hour preparation call was coordinated between the research team and project construction managers (or equivalent) to introduce the research study, provide instructions for application of the CPSA screening tool, and briefly run a tutorial of the tool. The project construction manager would then independently use a copy of the tool to identify applicable CPSAs for their specific project. A second one-hour debriefing interview call was coordinated between the research team and project construction managers to discuss lessons learned and determine if the tool required additional modifications. Findings and results from the CPSA screening tool demonstrations are discussed in Chapter 6 of this report.

Construction Phase Sustainability Metrics

CPSA Implementation Index

One of the objectives of this research was the development of recommended input and output metrics pertaining to construction sustainability. Sustainability metrics can help project teams self-evaluate sustainability implementation effort or impact performance against set targets; sustainability performance progress can also be measured over time. Accordingly, the research team pursued the development of a sustainability input metric named the CPSA Implementation Index to measure the breadth and extent of implementation of the 54 CPSAs. This initiative also resulted in the creation of a corresponding CPSA Implementation Index Calculator tool to further assist project teams in tracking construction sustainability effort and progress over time, in pursuit of an established goal. The development approach of the calculator tool was an expedited adaptation of the process used to construct the CPSA screening tool and comprised conceptualization, detailed planning, tool programming, and internal testing/debugging phases.

As part of the conceptualization phase the appropriate inputs, outputs, logic, and computational mechanics for the Implementation Index tool were evaluated. It was decided that the input would be based on the extent of implementation of individual CPSAs on a specific project. The output for the tool would be the CPSA Implementation Index score, a 100 point maximum scoring system in which points were evenly distributed between all 54 CPSAs (1.85 points per CPSA). Thus, user inputs would be collected in the form of affirmative responses to approximate the degree of application for each of the individual CPSAs; these entries would be converted to numerical scores ranging from 0 to 1.85 points. A final CPSA Implementation Index value would be computed through the sum of the scores for individual CPSAs.

Further outlining of the architecture and structure of the Implementation Index Calculator tool was performed during the detailed planning phase to optimize user interactions and leverage Excel's functions and capabilities. Like the CPSA screening tool, the Excel-based calculator tool is comprised of a resident database and five interface tabs. The resident database is accessible to the user and contains fixed data from the scoring model established by the research team, interprets user inputs for the level of individual CPSA application on the project, and computes the CPSA Implementation Index. The interface tabs are viewable to the user and is utilized to collect user inputs and present the CPSA Implementation Index score. The first two interface tabs provide introductory information and general guidance on the use and function of the calculator tool. The third and fourth interface tabs prompt the user to enter general project information and select/mark the extent to which individual CPSAs were implemented on the project. The last interface tab interacts with the resident database and displays the computed CPSA Implementation Index score.

During the programming phase, relevant information was extracted from the CPSA catalog entries and compiled into spreadsheet matrix format; computational mechanics and scoring models were then programmed into the resident database. Interface tabs were developed and additional features were created including: "back" and "next" buttons to navigate between user interfaces, pop-up messages to provide supplementary instructional guidance, and other visual aids. As part of the testing/debugging phase, the prototype calculator tool was distributed to the research team to perform a quality control assessment in order to evaluate the clarity of the information and instructions presented, ensure proper tool functionality and scoring computations, identify grammatical errors, and document other relevant concerns; the calculator tool was modified to address all research team comments. Additional information regarding the CPSA Implementation Index and calculator tool are discussed in Chapter 7 of this report.

Project Demonstrations for the CPSA Implementation Index Calculator

Project demonstrations of the CPSA Implementation Index Calculator were also conducted to assess the functionality and applicability of the tool on real world construction projects. Trial applications of the tool were performed on capital projects that were at the mid- or end-points of the construction phase to evaluate the extent of CPSA implementation and provide insight on potential areas for improvement.

Like the CPSA screening tool project applications, the demonstration for the Implementation Index Calculator consisted of a preparation/debriefing call, application of the tool, and a debriefing interview. A one-hour preparation call was coordinated between the research team and project construction managers (or equivalent) to introduce the research study, provide instructions for application of the Implementation Index tool, and briefly exhibit the tool. The project construction manager would then independently use a copy of the tool to evaluate CPSA implementation efforts on their specific project. A second one-hour debriefing interview call was coordinated between the research team and project construction managers to discuss lessons learned and determine if the tool required additional modifications. Findings and feedback from the Implementation Index Calculator demonstrations are discussed in Chapter 7 of this report.

Sustainability Performance Output Metrics

Output metrics focus on the actual achievement of one or more performance goals and are generally preferred over input effort- and resource-oriented metrics. As previously discussed relative to the completion of the CPSA catalog (field "G"), two output metrics were identified for each individual CPSA. As a supplement to the analysis approach presented earlier, detailed CPSA output metrics were tabulated to evaluate the most prevalent sustainability output metrics among the collection of 54 CPSAs. Trends and findings related to this analysis are provided in Chapter 7 of this report.

Construction Sustainability Process

Since this study produced a number of tools and implementation resources, it was decided that additional guidance should be provided to illustrate how project teams could integrate construction sustainability and CPSA implementation into existing conventional project planning and execution processes. Accordingly, recommended process steps were developed to incorporate sustainability within the context of capital projects. Assimilating these steps into existing industry procedures would helps to ensure the alignment of relevant work processes with the overall project goal and objectives.

Conceptualization and development of the construction sustainability process was performed during several team discussions and brainstorming sessions. Initially, a basic flowchart was created to chronologically outline representative milestones and tasks during the project planning and execution phase. The research team then determined the appropriate project milestones where tasks such as sustainability objectives and priorities development, use of the CPSA catalog/screening tool, and measurement of construction sustainability metrics could be incorporated into existing procedures. Crucial transitional events and necessary actions were included to ensure proper planning and performance evaluation of CPSA implementation efforts. Knowledge transfer and knowledge management techniques were also built into the sustainability process to further promote and advance future CPSA implementation success. The draft steps for the sustainability process were then further detailed and refined until the research team approved the recommended procedure. Additional information on the resulting construction sustainability process can be found in Appendix D.

CPSA-Specific Implementation Guidance

Going beyond the development of the CPSA catalog and implementation tools, the research team decided to pursue in-depth analysis for a select group of targeted CPSAs to showcase the variety of examination methods/tools available to further investigate a CPSA and to provide additional implementation guidance. Initially, brainstorming sessions were conducted to identify potential in-depth examination methods that could be applied to CPSAs. A listing of these methods, along with brief descriptions of each approach, is included in Appendix E.

With potential in-depth analysis methods established, several approaches were employed to target specific CPSAs for further investigation. Preliminary filtering of the 54 CPSAs was based on the sustainability impact ratings in field "C" of the CPSA catalog. Proxy numerical values were assigned to each of the five impact ratings and the sum of the values was computed for a total impact score. The CPSAs were then sorted by total impact score and grouped into high, medium, and low scoring CPSA groups. Team deliberations narrowed the selection down to four CPSAs from each scoring group for a total of 12 CPSAs.

Additional filtering of the twelve CPSAs was based on the CPSA's ease of implementation (field "E" of the CPSA catalog), applicable examination methods, and overall research team interest. It was decided that only CPSAs with moderate to challenging implementation would be considered for selection. Applicable examination methods for each CPSA were identified and CPSAs with the same analysis approach were removed until the remaining CPSAs had different evaluation processes. Further narrowing based on research team interest and perceived CPSA potential reduced the selection to 6 CPSAs.

Furthermore, work plans were developed for each of the remaining CPSAs in order to gain a high-level understanding of the scope of work for the in-depth examination. Final selection of CPSAs was based on work load, resource and schedule constraints, and the availability of information required to properly pursue the analysis. As a result, the following three CPSAs were targeted for an in-depth investigation:

- CPSA # 9: Paperless Communications and Construction Documentation
- CPSA # 28: Sustainable Temporary Facilities

- CPSA # 30: Source of On-Site Power

During the selection process the research team also decided to perform an Economic Input-Output Environmental Life Cycle Assessment (EIO-LCA) on a Galvanize Line project as a demonstrative case study. Information from this project was volunteered by research team members. Detailed information regarding in-depth analysis findings and resulting implementation guidance for these four developments can be found in Appendices F, G, H, and I.

Research Validation

Validation Process

Third party validation of research findings and associated research products was performed by an external panel of experts to identify critical missing content and significant corrections that were required. Qualified industry practitioners, other than the members of the research team, were identified by the research team to perform a high level review of the implementation resources which included: a report on major research findings, the CPSA catalog, information on the CPSA screening tool and implementation index calculator, the construction sustainability process, and construction phase sustainability metrics. Qualified reviewers included engineering and construction professionals who were designated experts in sustainability and/or had extensive experience in project construction management functions/positions.

Suitable candidates who volunteered to participate in the validation process were asked to complete a feedback document that consisted of two sections. The first section requested general background information from the participants including their name and contact information, company name, years of industry experience, and current job title. The second section asked for feedback comments and markups by the associated page and line number of the distributed resources. A sample research validation feedback template form is included in Appendix J. The feedback form and relevant resources were distributed along with an introductory email detailing the purpose of the research validation and completion/submission instructions.

Responses were collected in spreadsheet format for further analysis. Background information from the first section of the survey was used for collective characterization of the review panel while comments/mark-ups from the second section were processed and sorted into the following 8 categories of reaction to reviewer feedback:

- **A**: Reviewer agrees with draft; feedback is complimentary.
- **D**: RT disagrees with comment for good reason.
- **M**: Minor helpful elaboration provided.
- **N**: Comment is not in proper context or is essentially already accomodated.
- **S**: Substantive comment deserving a modification.
- **T**: Typo, format error, or word choice issue.
- **?**: Meaning of comment not clear.
- **D**: Requires further discussion to decide on which of the other categories this feedback belongs to.

Feedback from the external validation panel and the research team's subsequent reaction and modification to research products and findings are discussed in Chapter 8 of this report.

Characteristics of Reviewers

In total, the panel of external experts was comprised of 6 volunteers that were not part of the research team. The means years of personal industry experience was 29 years and was distributed across the construction and sustainability functions/professions.

Other Research Products

The research effort presented in the methodology resulted in the development of three reports along with associated tools and aids. The research summary report, RS 304-1, provides a succinct overview of the research activities that occurred over the course of this study and discusses the salient findings regarding the construction sustainability process and CPSA catalog. The implementation resource report, IR304-2, provides a detailed framework that will help companies better integrate sustainable field construction processes into their business and construction management practices; this report was designed to include practical implementation guidance on the construction sustainability process, CPSA catalog, CPSA screening tool, construction phase sustainability metrics, and CPSA-specific support for the three selected CPSAs. Files containing the CPSA screening tool and the CPSA implementation index calculator are included in the implementation report as separate implementation resources (IR 304-3 and IR 304-4, respectively). A hard copy of the CPSA poster, an artistic rendering of the listing of 54 CPSAs sorted by construction function, is also include in the implementation report. Lastly, this research report provides additional information on the technical aspects of the study; a detailed methodology of the data collection and analysis process is presented and associated research findings are discussed.

Chapter Four: Analysis of CPSA Catalog Information

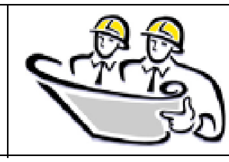
The research effort resulted in the identification and characterization of 54 CPSAs. This detailed information was assembled into a CPSA catalog that can be found in Appendix C of this report; the catalog is sorted by construction function. A sample catalog entry for one of the 54 CPSAs is shown below in Figure 4.1. The individual CPSA classifications contained in the catalog presented the opportunity to report and comment on collective characteristics of the 54 CPSAs. This section discusses the results of the analysis of CPSA catalog information.

A. CPSA NO.: 4

1. CPSA TITLE: Sustainability Provisions in Construction Execution Plans	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: Project Management	
3. SECONDARY CONSTRUCTION FUNCTION: None	

B. CPSA DESCRIPTION:

Incorporate sustainability provisions and solutions in the construction execution plans similar to provisions for safety, quality, cost, schedule, and resource management, among others. Include a discussion on sustainability requirements and opportunities as part of the preconstruction/kick-off meeting agenda to align the project team on sustainability objectives and expectations. Confirm that the team understands any sustainability specifications and assigns responsibilities and commitments for documentation.



C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	–	N	+	++
1. ENVIRONMENTAL	Energy consumption	Waste generation	Water consumption	☐	☐	☐	☒	☐
2. SOCIAL	Health & safety	Jobs created	Traffic	☐	☐	☐	☒	☐
3. ECONOMIC	Project fiscal impacts	-	-	☐	☐	☐	☒	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project safety performance: ☒	3. Project cost performance: ☒	5. None: ☐
2. Project quality performance: ☒	4. Project schedule performance: ☒	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☒	3. Challenging: ☐

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	Project management has taken a lead role in endorsing sustainability solutions
2	The project is large and complex
3	The project team has experience incorporating sustainability provisions

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Percent of projects with Sustainability Performance section in project reports
2	Contract requirement that sustainability be included in the project execution plan

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Unwillingness of project owner to incorporate sustainability provisions in the execution plan
2	Inexperience of staff to incorporate sustainability requirements into the execution plans

I. REFERENCES

1	Mendler, S. F., & Odell, W. (2000). *The HOK Guidebook to Sustainable Design*. New York: John Wiley & Sons, Inc.
2	Peters, E., Clermont, S., Culberson, S. D., Unzelman, R., Venzon, C. L., Kloiber, A., ... Eastmon, A. (2011a). *ACRP Report 42 - Sustainable Airport Construction Practices* (pp. 1–221). Washington D.C.: Airport Cooperative Research Program.
3	Varghese, J., & Webb, D. (2012). Contractor's Role During the Construction Phase. *Sustainable Construction Magazine*, (Winter 2012), 10–12.

Figure 4.1: Typical CPSA Catalog Entry

Construction Functions

Figure 4.2 below organizes the 54 CPSAs according to primary construction functions, and these eight functions are associated with the following number of CPSAs:

Construction Function	# of CPSAs	% of All
• **Project Management**	**10**	**19**
• Contracting	5	9
• **Field Engineering**	**10**	**19**
• **Site Facilities and Operations**	**12**	**22**
• Craft Labor Management	3	6
• Materials Management	6	11
• Construction Equipment Management	6	11
• Quality Management, Commissioning, and Handover	2	4

Nearly two-thirds of the actions pertain to the three construction functions of Project Management, Field Engineering, and Site Facilities and Operations.

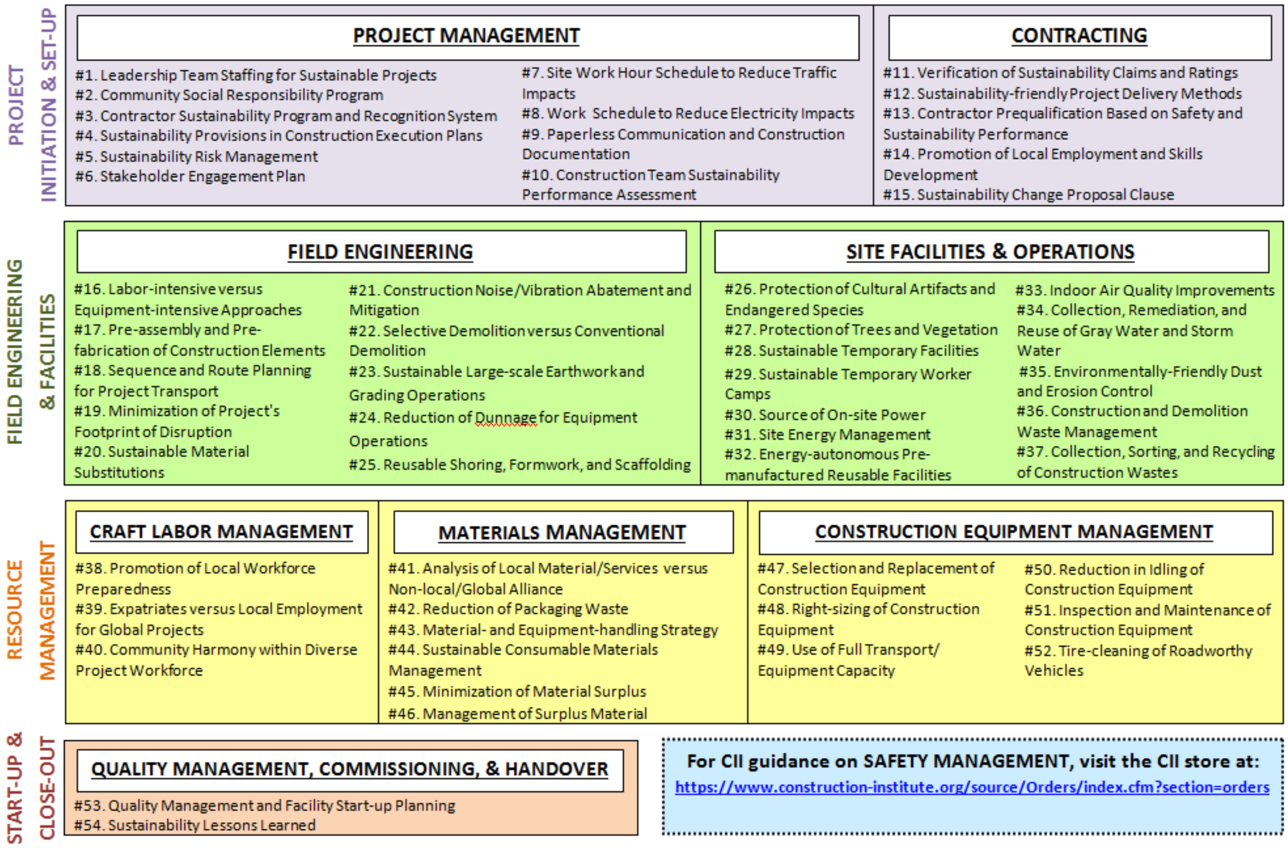


Figure 4.2: CPSAs according to Primary Construction Function

Impacts on Sustainability

The estimated sustainability impacts from CPSA implementation are shown in Figure 4.3 below. The results indicate that CPSAs most often enhance project environmental performance (89% of all CPSAs) and least often enhance economic performance (37%).

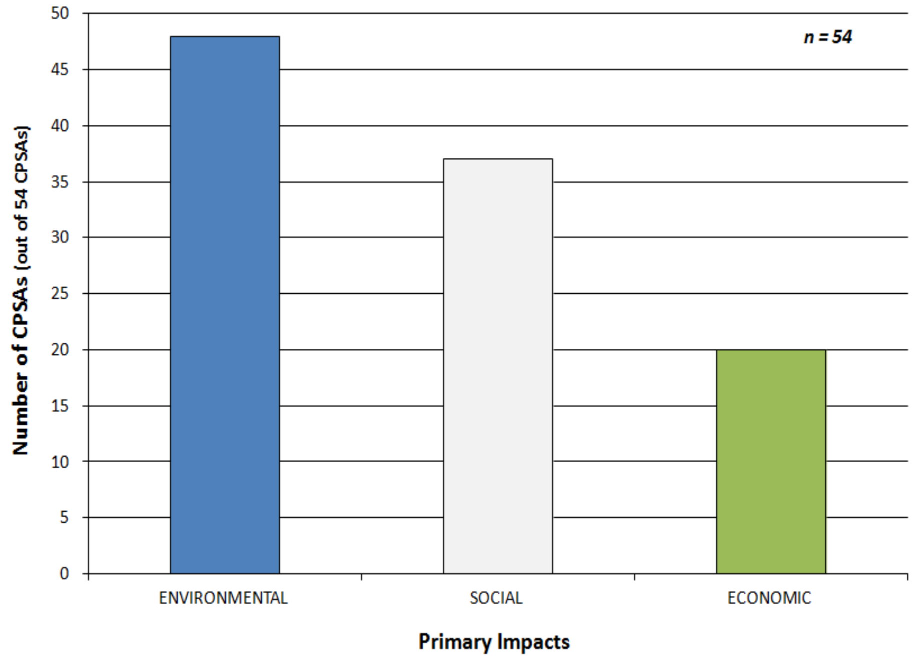


Figure 4.3: Frequency of Estimated Sustainability Impacts from CPSA Implementation

Figure 4.4 below examines these estimated impacts in greater detail. Within the environmental impacts, the most frequently affected areas pertain to energy consumption, waste generation, and greenhouse gases. Moreover, health and safety and community relationships are the most frequently affected social impacts. The most frequent economic impacts are associated with project fiscal impacts.

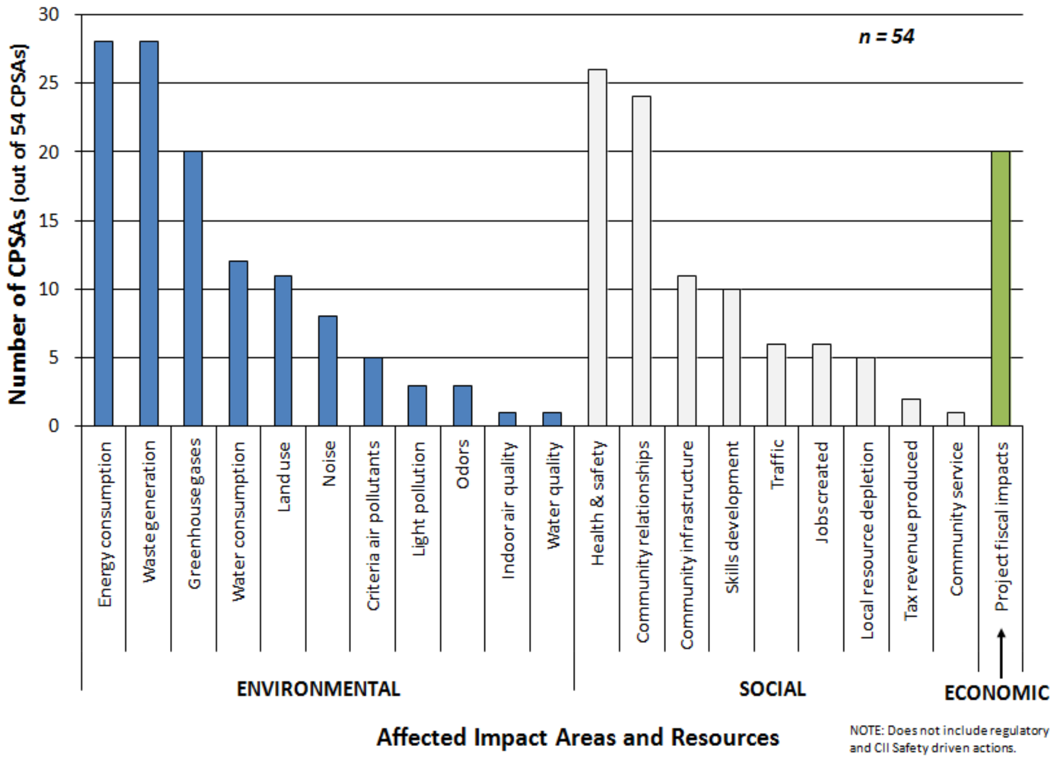


Figure 4.4: Specific Estimated Sustainability Impacts from CPSA Implementation

Impacts on Conventional Project Performance Criteria

CPSA support of conventional project performance criteria was also analyzed and presented in Figure 4.5 below. It was found that 20 out of 54 CPSAs (37%) can enhance cost performance, 28% of CPSAs can enhance safety, 28% of CPSAs can enhance schedule performance, and 13% of CPSAs can enhance quality performance. Approximately 46% of CPSAs, in general, provide no significant support to any of the four conventional project performance criteria. As previously discussed, construction actions that only affect safety were excluded from the scope of this study.

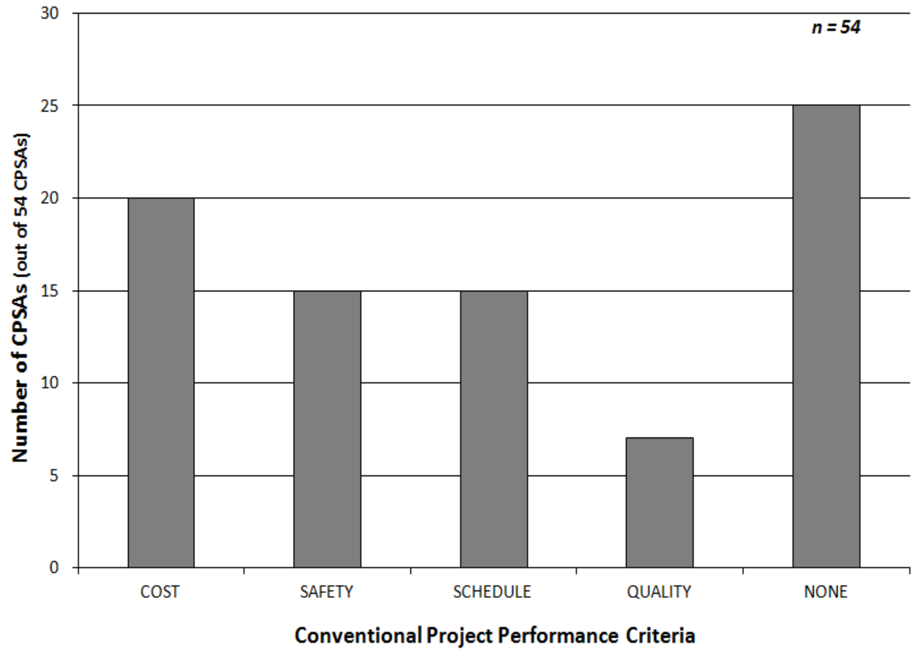


Figure 4.5: Frequency of Estimated CPSA Influence on Conventional Project Performance Criteria

Ease of Accomplishments/Implementation

Figure 4.6 below presents a summary of the ease of CPSA implementation evaluations performed by the research team. The results indicate that 7 of the 54 CPSAs (13%) should be relatively easy to implement, while 29 (54%) will require a moderate level of implementation effort, and 18 (33%) will be somewhat challenging to implement. The seven CPSAs regarded as easier to implement are listed in Table 4.1 below; these CPSAs are associated with a variety of construction functions.

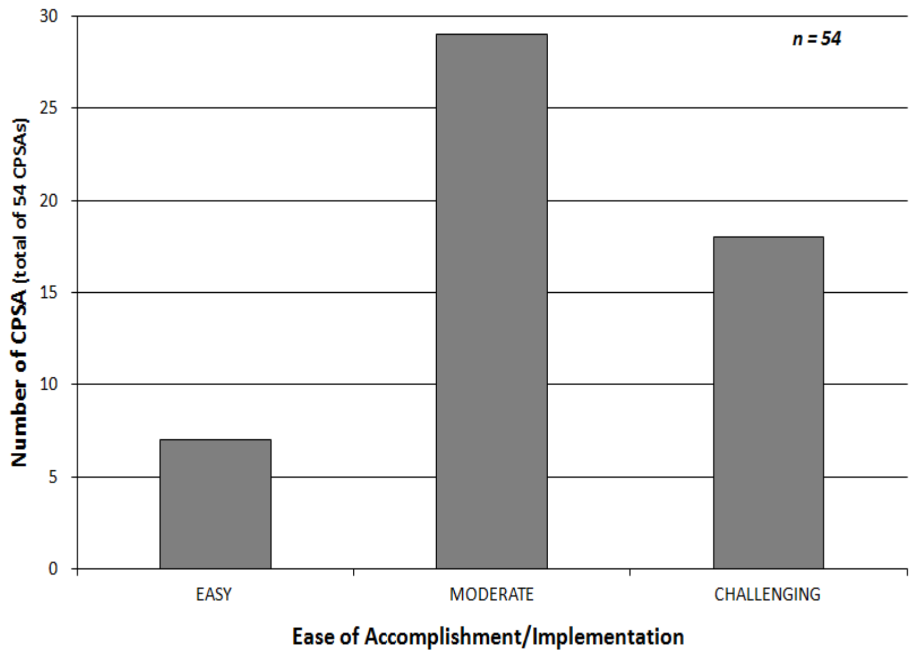


Figure 4.6: Estimated Ease of CPSA Accomplishment or Implementation

Table 4.1: CPSAs with Generally Greater Ease of Implementation

CPSA #	CPSA Title	Construction Function
3	Contractor sustainability program and recognition system	Project management
15	Sustainability change proposal clause	Contracting
25	Reusable shoring, formwork, and scaffolding	Field engineering
27	Protection of trees and vegetation	Site facilities and operations
44	Sustainable consumable materials management	Materials management
46	Management of surplus material	Materials management
52	Tire-cleaning of roadworthy vehicles	Construction equipment management

Project Conditions that Leverage Benefits

CPSA evaluations included the identification of three project conditions that leverage benefits for each individual CPSA. After consolidation of similar project conditions, a total of 112 leveraging project conditions were identified; a detailed tabulation of these project conditions can be found in Appendix K of this report. Analysis of the collection revealed that the following thirteen common leveraging project conditions were identified for three or more CPSAs; 35 out of 54 CPSAs (65%) had one or more of these project conditions.

- The project schedule and budget are flexible;
- The project is large and complex;
- The project involves a significant amount of demolition;
- The project site is small in size and congested;
- The project is located in an area with significant traffic congestion;
- Project stakeholders and local community leaders are clearly defined and accessible;
- The project owners, stakeholders, and/or local community have diverse interest relative to sustainability;
- The project team is interested in including, or has already incorporated, sustainability requirements into the prime contract;
- The project has a high local content requirements for materials and services;
- Project management has taken a lead role in endorsing sustainability solutions;
- The project is located in an environmentally/socially-sensitive area;
- The project is located in an area with recognized air quality problems; and
- Local recycling infrastructure is in place.

Figure 4.7 below further examines the collective leveraging conditions by categories that correspond to site characteristics and project execution processes. It was found that the most common project conditions pertain to the categories of project scope, health, safety and environment, procurement, project organization and project site.

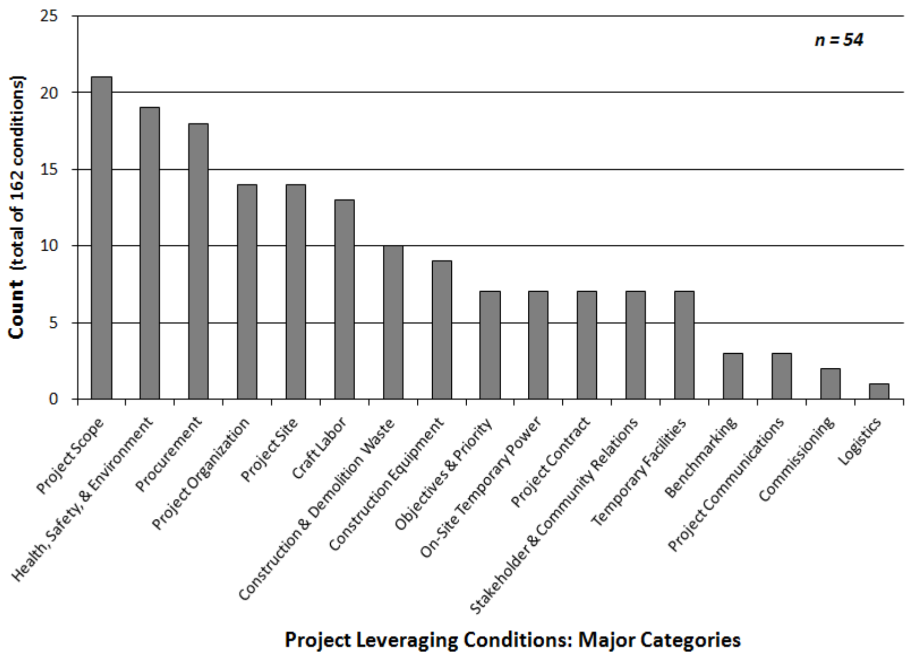


Figure 4.7: Categories of Common Project Conditions that Leverage Benefits from the CPSA

Sustainability Performance Output Metrics

Please refer to Chapter 7 for analysis results on sustainability performance output metrics.

Barriers to CPSA Implementation

As part of the CPSA characterization process, two common barriers to successful implementation of the subject CPSA were identified by the research team. An analysis of barrier category frequency is presented below in Figure 4.8 and indicates that the most frequent barrier types are lack of information and limited project resources. Together, these two types of barriers account for 59% of all barriers. The collection of detailed barriers, sorted by category of barriers, is included Appendix I. Project teams should be aware of all such implementation barriers and make efforts to reduce their occurrence and mitigate their effects.

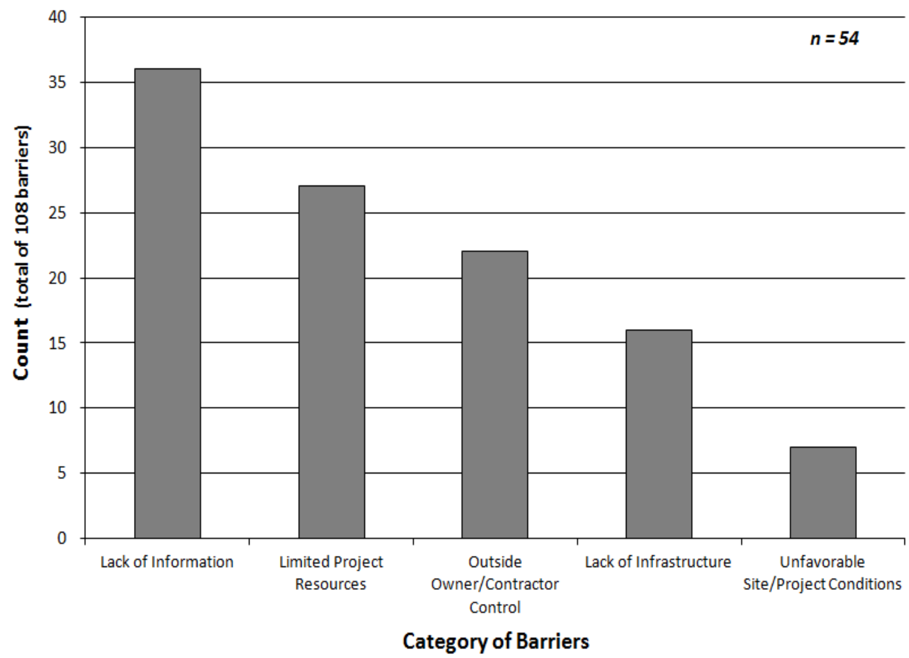


Figure 4.8: Categories of Common Barriers to CPSA Implementation

Chapter Five: CPSA Implementation Survey Findings

As part of this study, an industry survey was conducted to better understand current and future likely levels of individual CPSA implementation. This investigation also served to provide insight into how the industry perceives these CPSAs and help establish a benchmark on CPSA application. This section presents survey results and discusses findings.

The results of the survey are plotted in Figure 5.1 below. The distribution "cloud" illustrates a broad yet reasonable level of variation in current CPSA application, and an increasing trend of such application into the future. Regarding current levels of CPSA application, 40 CPSAs (74%) are *Sometimes* applied and one CPSA (2%) is *Frequently* applied. Regarding future levels of CPSA application, 40 CPSAs (74%) are *Somewhat Likely* to be applied and 13 CPSAs (24%) are *Very Likely* to be applied in the future. While 13 CPSAs (24%) are currently *Rarely* applied, only one CPSA (2%) is *Not Likely* to be applied in the future. The CPSA that is not likely to be applied in the future is CPSA #8, Work Schedule to Reduce Electricity Impacts. Otherwise, levels of CPSA implementation are expected to increase significantly in the future.

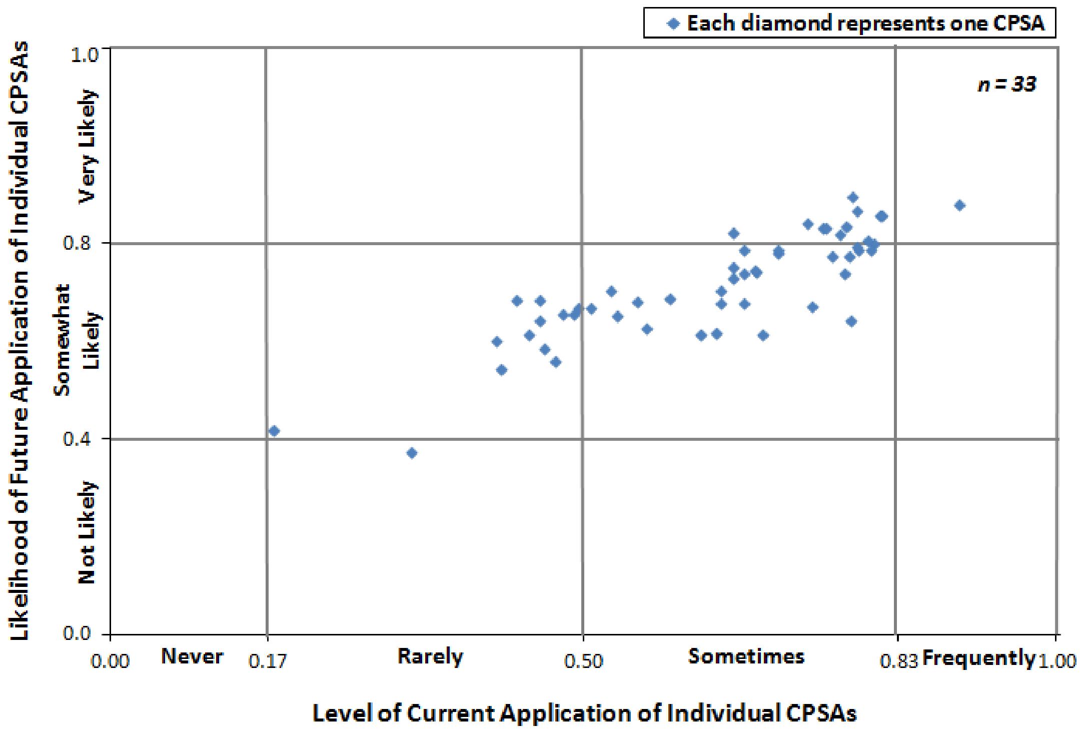


Figure 5.1: Current and Likely Future Application of the CPSAs

Beyond these observations, the research team used these findings as a reality cross-check or challenge to previous estimates of the "CPSA ease of implementation" field of the CPSA catalog (field "E"). This evaluation was based on the premise that easy-to-implement CPSAs should be more frequently implemented. While such a correlation between these two assessments was not totally as expected, the exceptions seem to be adequately explained by other considerations, such as magnitude of sustainability benefit or sustainability benefit-to-implementation cost ratio, among others.

Chapter Six: CPSA Screening Tool

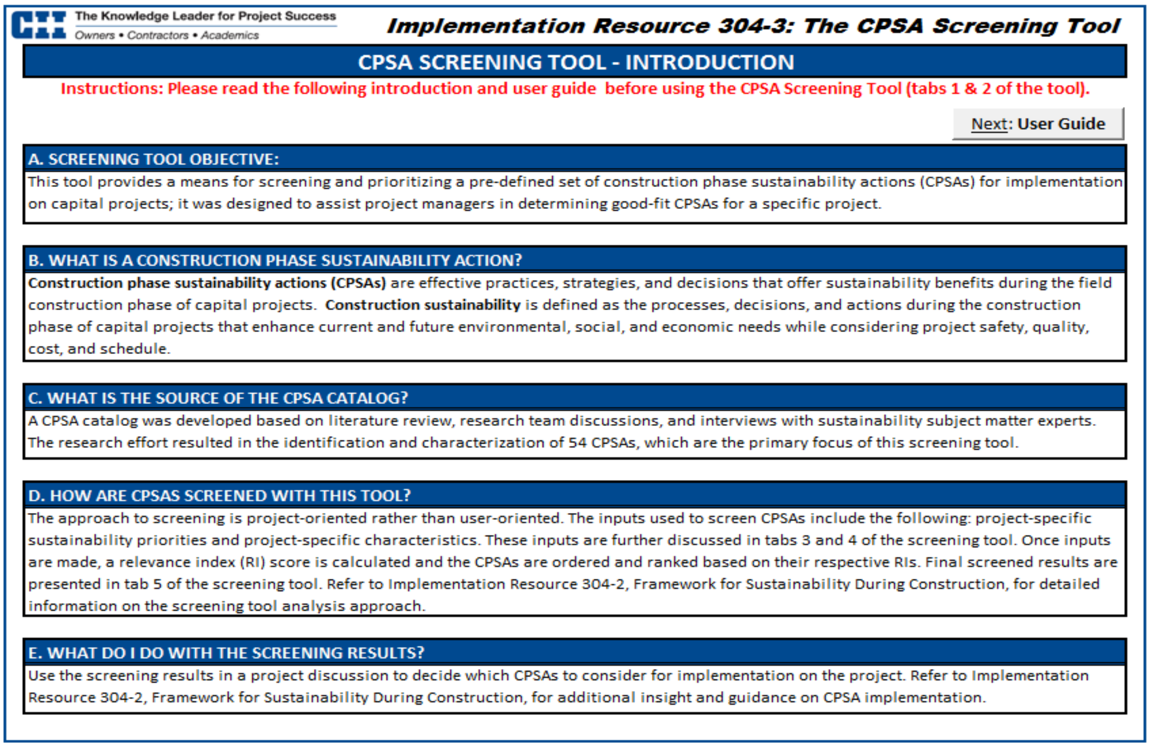
This section offers detailed information on the final CPSA screening tool's inputs, outputs, user interface, computational assumptions, and algorithms. Findings and learnings from the project demonstrations and screening tool applications are also presented.

Tool Inputs and Outputs

At first glance, a catalog of 54 CPSAs may pose a challenge to project teams seeking to select and implement a limited number of CPSAs for their project. In response to this concern, a tool was developed to provide a means for screening and prioritizing the 54 CPSAs for implementation on projects; the CPSA screening tool was designed to assist project managers in determining good-fit CPSAs that are more applicable for their project.

The final screening tool is an Excel spreadsheet that solicits user input on project-specific sustainability priorities and general project characteristics in order to generate a prioritized listing of better-fit CPSAs, given this information. Beyond these two types of user inputs, the tool relies upon tool-resident fixed data on CPSA sustainability impact types and relative magnitudes and knowledge of CPSA benefit-leveraging conditions, both of which are contained in the CPSA catalog itself (fields "C" and "F").

Screenshots from the Screening Tool (one for each of five tool tabs) are shown below in Figures 6.1 through 6.5; screening tool functions and logic are consistent with those described in the methodology section of this report (Chapter 3). The screening tool user interface features a total of five tabs. These tabs can be navigated by pressing the "next" and "back" buttons or clicking any of the tabs at the bottom of the interface. The user must first enter information into the "Sustainability Priorities" and "Project Conditions" tabs that is relevant to his/her project-specific objectives and characteristics, illustrated in Figures 6.3 and 6.4. Once these tabs are completed, the user can navigate to the screening tool results tab, presented in Figure 6.5, to review the screened CPSAs, which are ordered and ranked by most relevant to least relevant to the user's project. Supplemental instructions are provided in the form of pop-up messages and visual aids within each interface tab.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Implementation Resource 304-3: The CPSA Screening Tool

CPSA SCREENING TOOL - INTRODUCTION

Instructions: Please read the following introduction and user guide before using the CPSA Screening Tool (tabs 1 & 2 of the tool).

Next: User Guide

A. SCREENING TOOL OBJECTIVE:

This tool provides a means for screening and prioritizing a pre-defined set of construction phase sustainability actions (CPSAs) for implementation on capital projects; it was designed to assist project managers in determining good-fit CPSAs for a specific project.

B. WHAT IS A CONSTRUCTION PHASE SUSTAINABILITY ACTION?

Construction phase sustainability actions (CPSAs) are effective practices, strategies, and decisions that offer sustainability benefits during the field construction phase of capital projects. **Construction sustainability** is defined as the processes, decisions, and actions during the construction phase of capital projects that enhance current and future environmental, social, and economic needs while considering project safety, quality, cost, and schedule.

C. WHAT IS THE SOURCE OF THE CPSA CATALOG?

A CPSA catalog was developed based on literature review, research team discussions, and interviews with sustainability subject matter experts. The research effort resulted in the identification and characterization of 54 CPSAs, which are the primary focus of this screening tool.

D. HOW ARE CPSAS SCREENED WITH THIS TOOL?

The approach to screening is project-oriented rather than user-oriented. The inputs used to screen CPSAs include the following: project-specific sustainability priorities and project-specific characteristics. These inputs are further discussed in tabs 3 and 4 of the screening tool. Once inputs are made, a relevance index (RI) score is calculated and the CPSAs are ordered and ranked based on their respective RIs. Final screened results are presented in tab 5 of the screening tool. Refer to Implementation Resource 304-2, Framework for Sustainability During Construction, for detailed information on the screening tool analysis approach.

E. WHAT DO I DO WITH THE SCREENING RESULTS?

Use the screening results in a project discussion to decide which CPSAs to consider for implementation on the project. Refer to Implementation Resource 304-2, Framework for Sustainability During Construction, for additional insight and guidance on CPSA implementation.

Figure 6.1: Screenshot of Introduction Tab of CPSA Screening Tool (Tab 1 of 5)

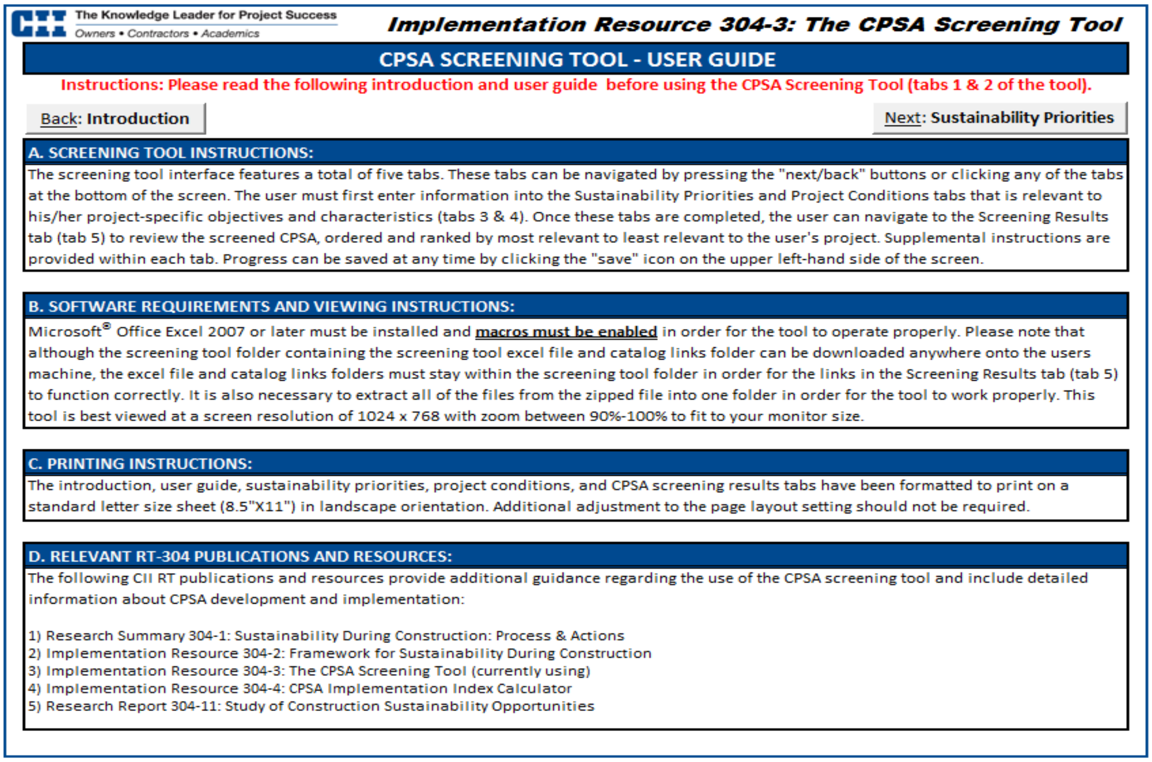


Figure 6.2: Screenshot of User Guide Tab of CPSA Screening Tool (Tab 2 of 5)

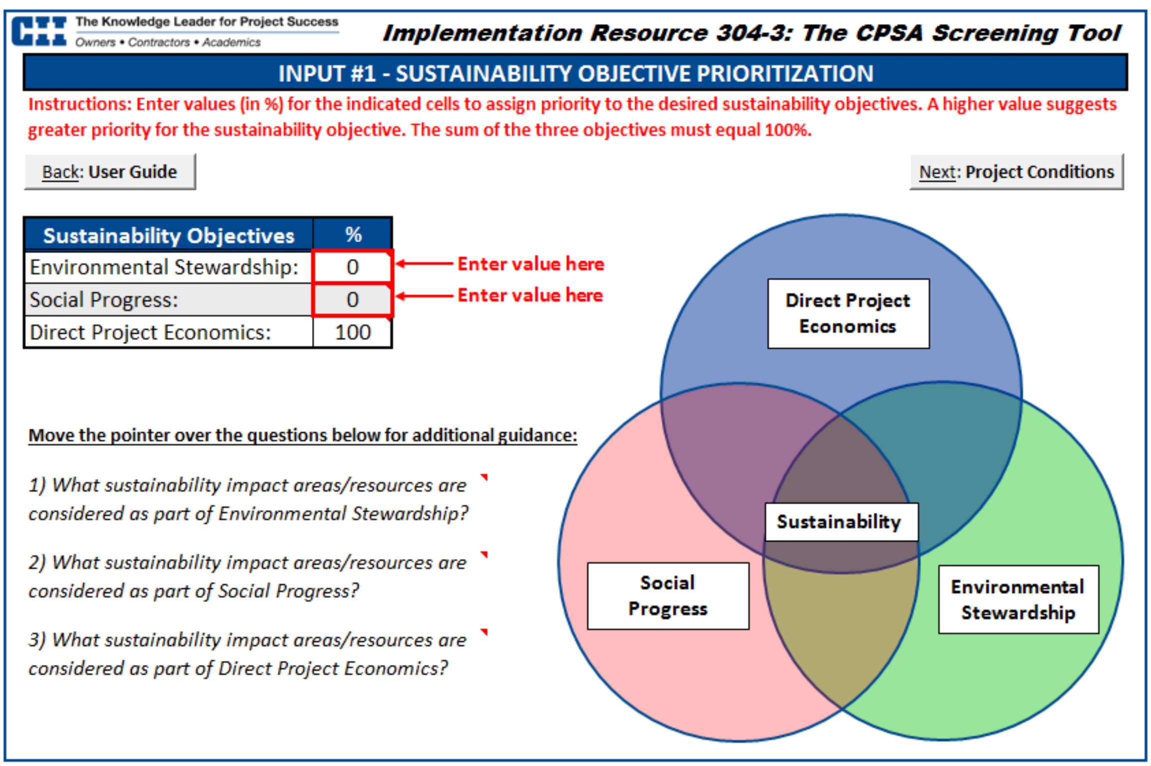
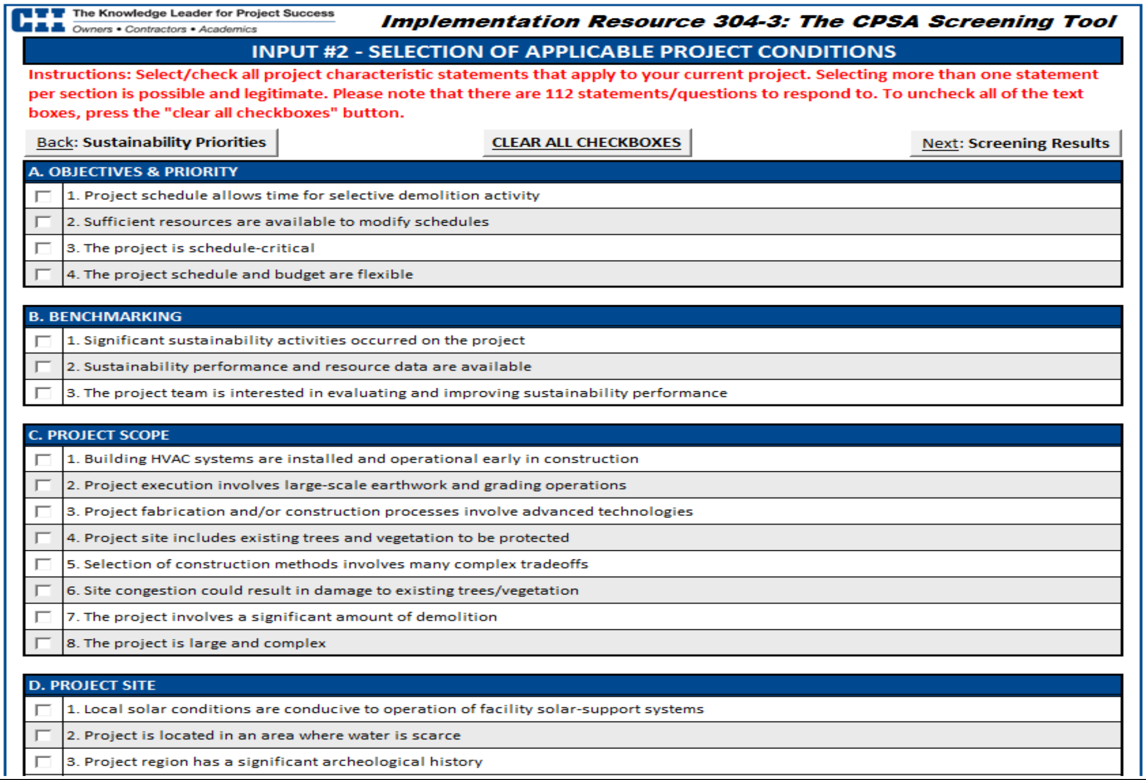


Figure 6.3: Screenshot of Input – Sustainability Priorities Tab (Tab 3 of 5)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Implementation Resource 304-3: The CPSA Screening Tool

INPUT #2 - SELECTION OF APPLICABLE PROJECT CONDITIONS

Instructions: Select/check all project characteristic statements that apply to your current project. Selecting more than one statement per section is possible and legitimate. Please note that there are 112 statements/questions to respond to. To uncheck all of the text boxes, press the "clear all checkboxes" button.

Back: Sustainability Priorities | **CLEAR ALL CHECKBOXES** | **Next: Screening Results**

	A. OBJECTIVES & PRIORITY
☐	1. Project schedule allows time for selective demolition activity
☐	2. Sufficient resources are available to modify schedules
☐	3. The project is schedule-critical
☐	4. The project schedule and budget are flexible

	B. BENCHMARKING
☐	1. Significant sustainability activities occurred on the project
☐	2. Sustainability performance and resource data are available
☐	3. The project team is interested in evaluating and improving sustainability performance

	C. PROJECT SCOPE
☐	1. Building HVAC systems are installed and operational early in construction
☐	2. Project execution involves large-scale earthwork and grading operations
☐	3. Project fabrication and/or construction processes involve advanced technologies
☐	4. Project site includes existing trees and vegetation to be protected
☐	5. Selection of construction methods involves many complex tradeoffs
☐	6. Site congestion could result in damage to existing trees/vegetation
☐	7. The project involves a significant amount of demolition
☐	8. The project is large and complex

	D. PROJECT SITE
☐	1. Local solar conditions are conducive to operation of facility solar-support systems
☐	2. Project is located in an area where water is scarce
☐	3. Project region has a significant archeological history

Figure 6.4: Partial Screenshot of Input – Project Conditions Tab (Tab 4 of 5)

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Implementation Resource 304-3: The CPSA Screening Tool

OUTPUT - CPSA SCREENING RESULTS

Instructions: Below are the CPSA screening results ranked and ordered by RI score. Refer to IR304-2 for guidance on CPSA implementation.

Back: **Project Conditions**

Rank	CPSA #	CPSA Title and Description	Leveraging Project Conditions	RI	Catalog Link
1	4	Sustainability Provisions in Construction Execution Plans: Incorporate sustainability provisions and solutions in the construction execution plans similar to provisions for safety, quality, cost, schedule, and resource management, among others. Include a discussion on sustainability requirements and opportunities as part of the preconstruction/kick-off meeting agenda to align the project team on sustainability objectives and expectations. Confirm that the team understands any sustainability specifications and assigns responsibilities and commitments for documentation.	a) Project management has taken a lead role in endorsing sustainable solutions b) The project is large and complex c) The project team has experience incorporating sustainability provisions	0.06	CPSA #4
2	5	Sustainability Risk Management: Ensure that sustainability risks are incorporated into the project risk management process by addressing environmental, social, and economic threats and opportunities. Perform a sustainability risk assessment to identify sources and root causes of accidents, releases or spills of hazardous material (i.e. exposure to the worker, community, and environment), and cultural clashes, among other events. Record such events in a Risk Register. Mitigation measures should be developed and employed to minimize negative sustainability impacts.	a) The project is large and complex b) The project is located in an environmentally/socially-sensitive area c) The project owner, stakeholders, and/or local community have diverse interests relative to sustainability	0.06	CPSA #5
3	9	Paperless Communication and Construction Documentation: Replace hardcopy-based communications with electronic/digital forms wherever possible. Consider developing and implementing digital data collection systems and real-time field reporting technologies to electronically streamline traditional paper-based processes and further reduce the reliance on paper files, drawings, and other documents during construction. Adopting green meeting practices can further reduce negative sustainability impacts. Examples of eco-friendly meeting practices include distributing meeting materials electronically, arranging meetings via telephone or Internet to reduce travel, and encouraging carpools or public transportation when travel cannot be avoided. If printing is required, modify the default setting of the printer to print double-sided and encourage recycling of all documents.	a) All parties are willing to use electronic communications and align on same electronic systems b) Electronic programs / forms are available and individuals with expertise are available to run them c) Projects where all parties have computers or tablets and knowledge of electronic systems	0.06	CPSA #9
4	13	Contractor Prequalification based on Safety and Sustainability Performance: Consider employing contractors and sub-contractors with sustainability experience and knowledge (e.g. LEED-accredited or Envision-certified staff). Routinely include safety performance in the prequalification of contractors, sub-contractors, and suppliers. Enhanced safety performance can have a major impact on the local	a) Sufficient number of contractors are available b) The project is large and complex c) The project owner, stakeholders, and/or local community have diverse interests relative to sustainability	0.06	CPSA #13

Figure 6.5: Partial Screenshot of Output – Screening Results Tab (Tab 5 of 5)

Tool Computation Assumptions and Algorithms

The CPSA Screening Tool generates a prioritized listing of CPSAs based on the computation of a Relevance Index (RI), a weighted composite numerical measure of the applicability of a CPSA to the user's project-specific sustainability objective priorities and general project characteristics (1.00 point maximum score). The formula below was used by the research team to calculate the RI for each CPSA.

$$\textbf{Relevance Index }(\textbf{RI}) = \textbf{Impact Score}(\textbf{IS}) \times \textbf{Conditions Score}(\textbf{CS})$$

where

$$\textbf{IS} = \sum[\textbf{Sustastainability Priorities }(\textbf{SP}) \times \textbf{Sustainability Impact Rating }(\textbf{SIR})]$$

The RI is comprised of two primary components: the impact score and the conditions score. The impact score (IS) is the weighted sum of the project-specific sustainability priorities (SP) and the sustainability impact rating (SIR) which is derived from sustainability impacts types (environmental, social, economic) and magnitudes for each CPSA. The SP is a percentage-based user input with a total sum of 100% that is distributed between environmental, social, and economic sustainability priorities. The SIR was developed by the research team and consists of the following scoring model:

- 0.00 if the SIR is N;
- 0.60 if the SIR is + (-0.06 if the SIR is -);
- 1.00 if the SIR is ++ (-1.00 if the SIR is - -);

The SIR is stored in the tool as resident fixed data and is also contained in the sustainability impacts characterization field of the CPSA catalog (field "C").

The conditions score (CS) is used to compare the user's general project characteristic, a user-input within the screening tool, to each of the CPSA's three project conditions that leverage benefits from the implementation of the CPSA. The CS was developed by the research team and consists of the following scoring model:

- 0.10 if 0 out of 3 CPSA leveraging conditions apply to the user's project characteristics;
- 0.33 if 1 out of 3 CPSA leveraging conditions apply to the user's project characteristics;

- 0.67 if 2 out of 3 CPSA leveraging conditions apply to the user's project characteristics;
- 1.00 if 3 out of 3 CPSA leveraging conditions apply to the user's project characteristics;

The leveraging conditions and scoring model for the CS are stored in the tool as resident fixed data; the leveraging conditions are also contained in the project conditions field of the CPSA catalog (field "F").

Once user inputs are made, the RI is calculated and the CPSAs are ordered and ranked from highest to lowest RI score. Final screened results include the CPSA's title and description, leveraging project conditions, and RI score; a hyperlink to the specific CPSA catalog entry is also provided to direct users to additional detailed information on the respective CPSA.

Demonstration Application Learnings

Details regarding the demonstration application learnings for the CPSA screening tool were not available at the time this thesis was written.

Chapter Seven: Construction Phase Sustainability Metrics

One of the objectives of this research was the development of recommended input and output metrics pertaining to construction sustainability. Sustainability metrics can help project teams self-evaluate sustainability implementation effort or impact performance against set targets; sustainability performance progress can also be measured over time. Such metrics usually come in one of two forms: input-oriented or output-oriented metrics. Input metrics typically measure the breadth and/or extent of effort applied in the pursuit of an established goal, while output metrics focus on the actual achievement of one or more performance goals. Research efforts resulted in the conception of the CPSA Implementation Index and associated calculator tool as an over-arching input metric pertaining to construction sustainability. Moreover, a list of CPSA-specific output metrics was generated as a result of the CPSA catalog development process. This section offers detailed information on the final CPSA Implementation Index Calculator tool's design, intended usage, and findings from the project demonstrations. Results from the analysis of CPSA-specific sustainability performance output metrics are also presented.

CPSA Implementation Index

Index Calculator Tool: Design and Intended Usage

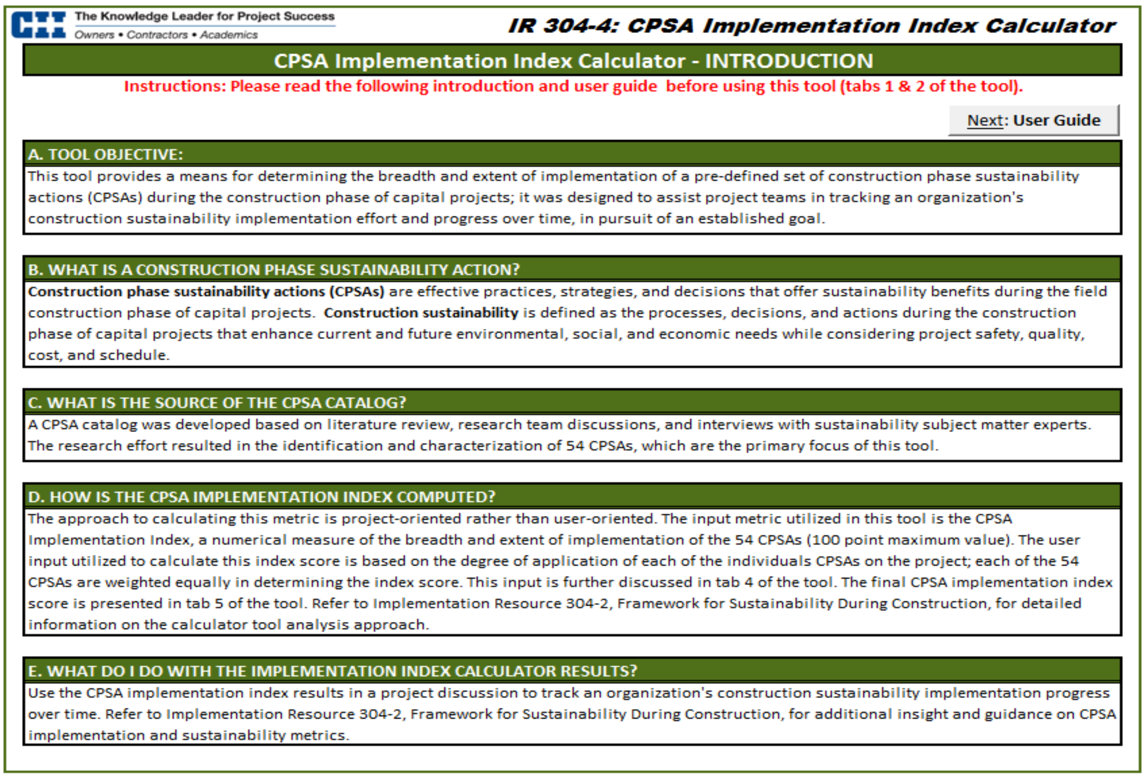
The input metric recommended for project teams is the CPSA Implementation Index. This index is a numerical measure (100 point maximum score) of the breadth and extent of implementation of the 54 CPSAs. In the determination of the Index score, each of the 54 CPSAs earns the following points, depending on the extent of implementation of the individual CPSA on the project:

	Points Earned (per CPSA)
• None or almost no implementation (less than 20% complete)	**0.00**
• Minimal partial implementation (between 20 and 50% complete)	**0.62**
• Substantial partial implementation (between 50 and 80% complete)	**1.23**
• Full or almost complete implementation (more than 80% complete)	**1.85**

As each of the 54 CPSAs is weighted equally in the determination of the Index, the points earned for full credit is computed as 100 points divided by 54 (the number of CPSAs), which equates to 1.85 points per CPSA. The intermediate point values (of 0.62 and 1.23) are 33% and 67% pro-rata values of the 1.85 points for full credit.

The corresponding CPSA Implementation Index Calculator tool was designed to automatically perform these computations and further assist project teams in tracking construction sustainability implementation efforts and progress over time, in pursuit of an established goal. It is recommended that CPSA Implementation Index assessments be conducted at both mid- and end-points of the Construction Phase (see the recommended construction sustainability process in Appendix D). The final calculator tool is an Excel spreadsheet that solicits user input on the level of CPSA implementation efforts in order to generate a CPSA Implementation Index score. Beyond this information, the tool relies upon tool-resident fixed data derived from the index scoring model presented above.

Screenshots of the CPSA Implementation Index Calculator tool's user interface are shown below in Figures 7.1 through 7.5; the tool's functions and logic are consistent with those described in the methodology section of this report (Chapter 3). The calculator tool user interface features a total of five tabs. These tabs can be navigated by pressing the "next" and "back" buttons or clicking any of the tabs at the bottom of the interface. In the "Project Information" tab, presented in Figure 7.3, the user can enter general information regarding the project and the evaluator performing the assessment for record-keeping purposes; these fields are optional and do not impact results. The user must also enter information into the "Implementation Effort" tab that is relevant to his/her project-specific implementation of individual CPSAs, illustrated in Figure 7.4. The user can then navigate to the "Implementation Index" tab, shown in Figure 7.5, to review the computed index score relevant to the project. Supplemental instructions are provided in the form of pop-up messages and visual aids within each interface tab.



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IR 304-4: CPSA Implementation Index Calculator

CPSA Implementation Index Calculator - INTRODUCTION

Instructions: Please read the following introduction and user guide before using this tool (tabs 1 & 2 of the tool).

Next: User Guide

A. TOOL OBJECTIVE:

This tool provides a means for determining the breadth and extent of implementation of a pre-defined set of construction phase sustainability actions (CPSAs) during the construction phase of capital projects; it was designed to assist project teams in tracking an organization's construction sustainability implementation effort and progress over time, in pursuit of an established goal.

B. WHAT IS A CONSTRUCTION PHASE SUSTAINABILITY ACTION?

Construction phase sustainability actions (CPSAs) are effective practices, strategies, and decisions that offer sustainability benefits during the field construction phase of capital projects. **Construction sustainability** is defined as the processes, decisions, and actions during the construction phase of capital projects that enhance current and future environmental, social, and economic needs while considering project safety, quality, cost, and schedule.

C. WHAT IS THE SOURCE OF THE CPSA CATALOG?

A CPSA catalog was developed based on literature review, research team discussions, and interviews with sustainability subject matter experts. The research effort resulted in the identification and characterization of 54 CPSAs, which are the primary focus of this tool.

D. HOW IS THE CPSA IMPLEMENTATION INDEX COMPUTED?

The approach to calculating this metric is project-oriented rather than user-oriented. The input metric utilized in this tool is the CPSA Implementation Index, a numerical measure of the breadth and extent of implementation of the 54 CPSAs (100 point maximum value). The user input utilized to calculate this index score is based on the degree of application of each of the individuals CPSAs on the project; each of the 54 CPSAs are weighted equally in determining the index score. This input is further discussed in tab 4 of the tool. The final CPSA implementation index score is presented in tab 5 of the tool. Refer to Implementation Resource 304-2, Framework for Sustainability During Construction, for detailed information on the calculator tool analysis approach.

E. WHAT DO I DO WITH THE IMPLEMENTATION INDEX CALCULATOR RESULTS?

Use the CPSA implementation index results in a project discussion to track an organization's construction sustainability implementation progress over time. Refer to Implementation Resource 304-2, Framework for Sustainability During Construction, for additional insight and guidance on CPSA implementation and sustainability metrics.

Figure 7.1: Screenshot of Introduction Tab of Implementation Index Calculator (Tab 1 of 5)

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IR 304-4: CPSA Implementation Index Calculator

CPSA Implementation Index Calculator - USER GUIDE

Instructions: Please read the following introduction and user guide before using this tool (tabs 1 & 2 of the tool).

Back: Introduction | Next: Project Information

A. TOOL INSTRUCTIONS:

The CPSA implementation index calculator features a total of five tabs. These tabs can be navigated by pressing the "next/back" buttons or clicking any of the tabs at the bottom of the screen. In the Project Information tab (tab 3), the user can enter general information regarding the project and the evaluator performing the assessment for record-keeping purposes; these fields are optional and will not impact results. Next, the user must enter information into the Implementation Effort tab that is relevant to his/her project-specific implementation of individual CPSAs (tab 4). Once this tab is completed, the user can navigate to the Implementation Index tab (tab 5) to review the computed index score relevant to the user's project. Supplemental instructions are provided within each tab. Progress can be saved at any time by clicking the "save" icon on the upper left-hand side of the screen.

B. SOFTWARE REQUIREMENTS AND VIEWING INSTRUCTIONS:

Microsoft® Office Excel 2007 or later must be installed and **macros must be enabled** in order for the tool to operate properly. The tool folder containing the Implementation Index Calculator excel file can be downloaded anywhere onto the users machine. It is also necessary to extract all of the files from the zipped file into one folder in order for the tool to work properly. This tool is best viewed at a screen resolution of 1024 x 768 with zoom between 90%-110% to fit to your monitor size.

C. PRINTING INSTRUCTIONS:

The introduction, user guide, implementation effort, and implementation index tabs have been formatted to print on a standard letter size sheet (8.5"X11") in landscape orientation. Additional adjustment to the page layout setting should not be required.

D. RELEVANT RT-304 PUBLICATIONS AND RESOURCES:

The following CII RT publications and resources provide additional guidance regarding the use of the CPSA Implementation Index Calculator and include detailed information about CPSA development and implementation, and sustainability metrics:

1) Research Summary 304-1: Sustainability During Construction: Process & Actions
2) Implementation Resource 304-2: Framework for Sustainability During Construction
3) Implementation Resource 304-3: The CPSA Screening Tool
4) Implementation Resource 304-4: CPSA Implementation Index Calculator (currently using)
5) Research Report 304-11: Study of Construction Sustainability Opportunities

Figure 7.2: Screenshot of User Guide Tab of Implementation Index Calculator (Tab 2 of 5)

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IR 304-4: CPSA Implementation Index Calculator

INPUT - PROJECT INFORMATION

Instructions: Please enter the following information related to the project. All fields are optional and will not impact computations.

Back: User Guide | Next: Implementation Effort

A. GENERAL PROJECT INFORMATION:

Project Name: ______	**Project ID / Ref. #:** ______
Project Client Name: ______	**Client ID/ Ref. #:** ______
Project General Contractor: ______	**Contractor ID/Ref. #:** ______

B. PROJECT DESCRIPTION:

Enter a brief description of the project here.

C. ADDITIONAL INFORMATION:

Evaluator Name: ______	**Evaluation Date:** ______
Project Affiliation (select one): ○ Owner ○ Contractor	**Construction Completed (%):** ______ %
E-mail: ______	**Telephone:** ______

List other contributors that were consulted during the evaluation:

1. ______
2. ______
3. ______
4. ______

Figure 7.3: Screenshot of Input – Project Information Tab (Tab 3 of 5)

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IR 304-4: CPSA Implementation Index Calculator

INPUT - CPSA IMPLEMENTATION EFFORT CHECKLIST

Instructions: Please read the descriptions for the following 54 CPSAs and select/check the degree to which the CPSAs were implemented on your project.

Back: User Guide | CLEAR ALL CHECKBOXES | Next: Implementation Index

CPSA Title and Description	Extent of CPSA Implementation					Comments:
	None or almost none	Minimal	Substantial	Full or almost full	Not Applicable	
CPSA #1. Leadership Team Staffing for Sustainable Projects: Seek to establish a "hearts and minds" sustainability-oriented culture much like organizations pursue a safety or quality culture. Employ administrative staff that possess skills and experience in the management of sustainable projects. Identify voids in knowledge and be prepared to offer supplemental training on project environmental and community impacts, worker safety cultures, effective project communication, etc.	○	○	○	○	○	
CPSA #2. Community Social Responsibility Program: Consider establishing a formal community social responsibility program as a way to respond to stakeholder needs. Formal community signoffs on individual initiatives can be very beneficial. Related volunteer-based programs can have a significant impact as well. This responsibility program should include the development and maintenance of a project website for the local community and holding community forums to discuss project issues, such as traffic impacts and upcoming construction work.	○	○	○	○	○	
CPSA #3. Contractor Sustainability Program and Recognition System: The project team and its subcontractors/suppliers should establish and implement a sustainability program with a recognition system that rewards innovation and effectiveness. Identify sustainability program responsibilities and performance expectations for key personnel. Provide rewards for sustainable performance that meets or exceeds program expectations. The reward program should address all three dimensions of sustainability.	○	○	○	○	○	
CPSA #4. Sustainability Provisions in Construction Execution Plans: Incorporate sustainability provisions and solutions in the construction execution plans similar to provisions for safety, quality, cost, schedule, and resource management, among others. Include a discussion on sustainability requirements and opportunities as part of the preconstruction/kick-off meeting agenda to align the project team on sustainability objectives and expectations. Confirm that the team understands any sustainability specifications and assigns responsibilities and commitments for documentation.	○	○	○	○	○	

Figure 7.4: Screenshot of Input – CPSA Implementation Effort Checklist Tab (Tab 4 of 5)

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IR 304-4: CPSA Implementation Index Calculator

OUTPUT - CPSA IMPLEMENTATION INDEX

Instructions: Below is the computed CPSA Implementation Index and a summary of implementation index calculations. Refer to IR304-2 for guidance on CPSA implementation and sustainability metrics.

Back: Implementation Effort

CPSA Implementation Index = 0 out of 100 points
= 0 out of 100 %

Summary of CPSA Implementation Index Calculations

Extent of CPSA Implementation	CPSA Count	Section Score
None or almost none	54	0.00
Minimal	0	0.00
Substantial	0	0.00
Full or almost full	0	0.00
Not applicable	0	N/A
CPSA Implementation Index	**54**	**0.00**

Figure 7.5: Screenshot of Output – CPSA Implementation Index Tab (Tab 5 of 5)

Demonstration Application Learnings

Details regarding the demonstration application learnings for the CPSA Implementation Index calculator were not available at the time this thesis was written.

Analysis of CPSA Sustainability Performance Output Metrics

Output metrics focus on the actual achievement of one or more performance goals and are generally preferred over input effort- and resource-oriented metrics. As previously discussed relative to the completion of the CPSA catalog (field "G"), two output metrics were identified for each individual CPSA. Consolidation of similar metrics resulted in a register of 59 sustainability performance output metrics; a detailed tabulation of these output metrics by category of metric is presented in Table 7.1 below. Review of the collection revealed that 28 of the 54 CPSAs (52%) may be assessed with one or more of the following seven predominant output metrics; four of these seven more prevalent metrics pertain to environmental performance.

- Percent of projects with Sustainability Performance section in project reports;
- Cost savings;
- Portion or volume of total waste recycled or diverted from a landfill;
- Street value of recycled material;
- Equipment environmental performance;
- Size of carbon footprint from project; and
- Number of complaints from community, agency, or camp residents.

Table 7.1: Construction Sustainability Output Metrics

Item #	CATEGORY OF METRIC	CPSA #	Output Metric
1	Benchmarking	1, 4, 10, 54	Percent of projects with Sustainability Performance section in project reports
2		1, 54	Percent of projects that document sustainability lessons-learned
3		3, 10	Project-over-project or year-over-year comparison of one or more specific sustainability metrics

Table 7.1: Construction Sustainability Output Metrics (continued)

Item #	CATEGORY OF METRIC	CPSA #	Output Metric
4		5, 26	Portion of sustainability risks that are effectively mitigated
5		5	Cost and/or schedule savings from sustainability risk avoidance or mitigation
6		7	Periodic traffic counts on major arterials near the jobsite
7		13, 17	Contractor safety performance vs. target
8		26	Time impact on project schedule
9	Contracting & Procurement	4, 53	Contract requirement that sustainability be included in the project execution plan
10		11	Percent of corporate purchases that consider sustainability claims in the prequalification process
11		11	Percent of suppliers and vendors that have at least one sustainability certification
12		12, 15	Sustainability change proposal clause (similar to Value Engineering) is included in the prime contract
13		12	Sustainability objectives are stated in the prime contract
14		14	Dollar value of MBE/ WBE/SBEs contracts
15		14	MBE/WBE/SBE contracts as a percent of all contracts
16		16, 39, 41	Change in local employment from project (percent or number)
17		18	Proportion of delivery arrivals during peak traffic hours
18		41	Contribution of project to local tax revenue
19		43, 50	Cycle time from material request to material site delivery
20		49	Proportion of truck deliveries that are at or near full capacity
21	Work Processes	3	Number of annual awards for sustainability contributions
22		8	Percent of craft work hours performed in night shift
23		9	Approximate number of hard copy documents (pages) transferred to owner at final handover
24		9	Percent of project documentation managed electronically
25		13	Percent of project contracts that incorporate sustainability issues as a part of contractor prequalification
26		25, 32, 44, 45	Cost savings

Table 7.1: Construction Sustainability Output Metrics (continued)

Item #	CATEGORY OF METRIC	CPSA #	Output Metric
27	**Construction & Demolition Waste**	17, 22, 24, 25, 36, 37, 42, 44, 45, 46	Portion or volume of total waste recycled or diverted from a landfill
28		22, 24, 42, 46	Street value of recycled material
29		23	Earthwork quantity reduced or eliminated
30		34, 52	Quantity of grey water reused
31		36, 37	Reduction in landfill tipping fees
32	**Labor & Staff**	16	Field productivity
33		29, 39	Effort or resources required to reach employment targets (per hired craft worker or PM staff)
34		29	Level of satisfaction of workers living in project camp
35		38, 40	Local workforce turnover rate
36		38	Number of labor skill certifications awarded annually
37	**Equipment**	23, 43, 47, 51	Equipment environmental performance
38		47, 48	Fuel consumption efficiency
39		48	Change in equipment rental expense
40		49	Equipment capacity utilization
41		50	Amount of vehicle idling
42		51	Equipment inspection frequency
43	**Facility Commissioning**	33	HVAC testing performance
44		53	Commissioning resource efficiency
45	**Environmental Footprint**	8	Percent of jobsite electricity from renewable sources
46		15, 20	Number of changes/substitutions to environmentally friendly materials
47		18, 35	Local air quality metrics
48		19, 27, 28	Proportion of sensitive vegetation not impacted from project
49		19, 27	Number of significant trees impacted from project
50		20, 28, 30, 31	Size of carbon footprint from project
51		21	Reduction in measured noise level
52		30	Amount of particulate matter from site power sources
53		31	Power consumption per basis unit ($K of construction, K work hours, etc.)

Table 7.1: Construction Sustainability Output Metrics (continued)

Item #	CATEGORY OF METRIC	CPSA #	Output Metric
54		33	Indoor air quality test results
55		34	Reduction in consumption of potable water
56	**Community or User Satisfaction**	2, 6	Percent of community issues addressed
57		2, 6	Percentage of stakeholder engagement plan that is implemented
58		7, 21, 35, 40, 52	Number of complaints from community, agency, or camp residents
59		32	Facility user satisfaction level

Figure 7.6 below examines this collection using categories of output metrics. The most common output metrics pertain to the categories of environmental footprint, construction and demolition waste, contracting and procurement, and benchmarking.

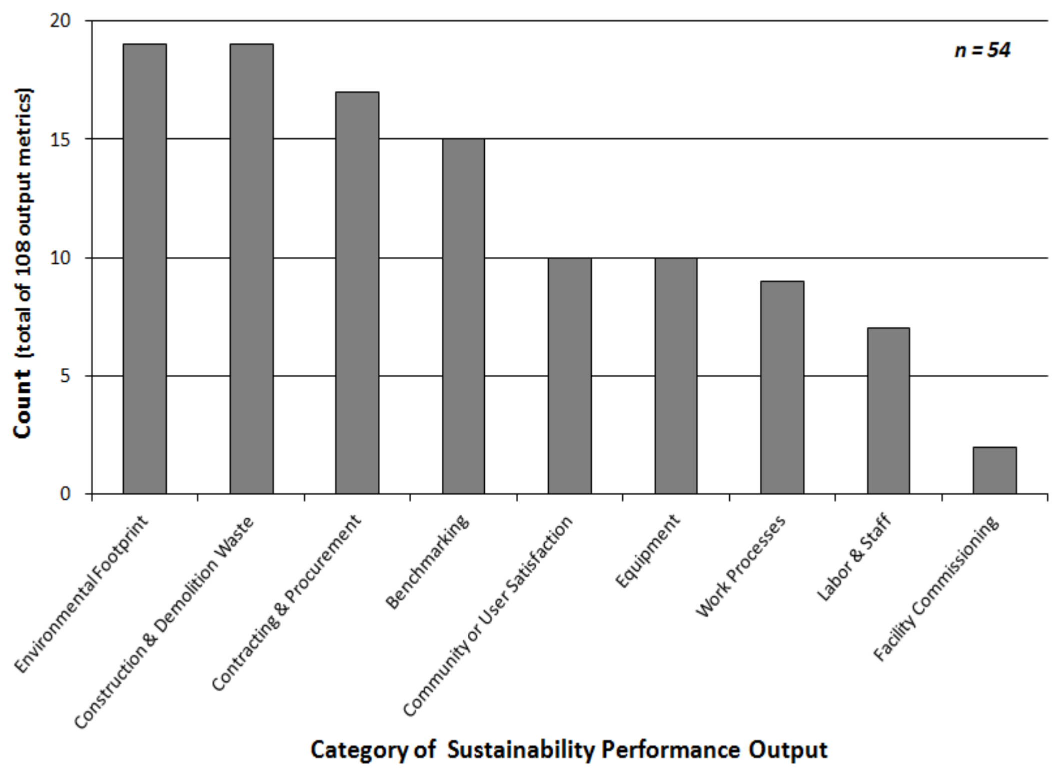


Figure 7.6: Categories of Output Metrics

Chapter Eight: Validation Feedback and Research Team Reaction

This section presents the results of the third party validation effort that was conducted to identify critical missing content and significant corrections that were required for research findings/products. An overview of subsequent modifications and reactions to this feedback are also discussed.

Panel Feedback and Research Team Reactions

A total of 85 comments were provided by the six external panel reviewers. Table 8.1 below presents a summary of reviewer feedback sorted into these categories. Initially, 16 out of the 85 comments were assigned a category of "G" and were further discussed by the research team; these mark-ups were then reallocated to one of the other seven categories. It was determined that 18 out of the 85 comments (21%) would require modification of the research products in some form (categories "M", "S", or "T"). The following section details subsequent modifications and research team reaction to this feedback.

Table 8.1 External Review Panel Feedback and RT Responses

Item	Category Type Code	Comment Type & RT Response	# of Comments	% of total	Content Modified?
1	**A**	Review agrees with draft; feedback is complimentary	**16**	**19**	**NO**
2	**D**	RT disagrees with comment for good reason	**21**	**25**	**NO**
3	**M**	Minor helpful elaboration is provided	**3**	**3**	**YES**
4	**N**	Comment is not in proper context or is essentially already accommodated	**25**	**29**	**NO**
5	**S**	Substantive comment deserving a modification	**11**	**13**	**YES**
6	**T**	Typo, format error, or word choice issue	**4**	**5**	**YES**
7	**?**	Meaning of comment not clear	**5**	**6**	**NO**
		TOTAL	**85**	**100**	**-**

Overview of Modifications and Path-Forward from Feedback

Details regarding the modifications and path-forward from feedback were not available at the time this thesis was written.

Chapter Nine: Discussion

The results discussed in chapter 8 are based upon an informal assay of judgment from construction project managers and facility/infrastructure owners. Other sustainability-driven decision-support resources that are similarly based upon expert judgment have been shown to reflect bias when outcomes are compared to real measures of resource and economic flows. This discussion is therefore aimed at identifying opportunities to improve future research on sustainability practices during the construction phase of capital projects.

Reflection on Research Approach and Study Findings

The research approach employed for this study sought to investigate current advances in construction sustainability through literature review and communication with industry experts and sustainability practitioners. To further supplement this initiative, industry surveys and external research validations were conducted to provide insight into current levels of individual CPSA application, to gauge overall industry perception of construction sustainability practices, and identify critical missing content in research findings. Ultimately, this methodology resulted in the creation of one of the most comprehensive collections of project-level construction sustainability practices currently available to the construction sector. The study's emphasis on project-level sustainability practices and continuous input from construction professionals allowed the development of practical implementation guidance that is truly construction-centric and will be readily accessible to project teams from both contractor and owner companies. While these advancements are a step forward in construction sustainability, it is one of many developments that will be required for the successful implementation of project-level sustainability practices on capital projects.

CPSA prioritization and performance would be significantly improved with more robust empirical and theoretical analyses using established and objective decision-support methodologies. Examination methods such as life-cycle assessment (LCA), benefits-cost analysis (BCA), cost-effectiveness (CE), and uncertainty and variability analysis provide systematic approaches that can be used to quantify the sustainability impacts associated with existing conventional construction processes and the proposed sustainable alternatives. Moreover, data describing project expenditures, environmental flows, and social indicators such as employment, community complaints, and traffic would prove invaluable in advancing a rigorous understanding of highlighted CPSA. These efforts can also shed light on the most appropriate sustainability output metrics that can be used to measure a CPSA's field implementation performance.

Individual CPSAs can then be implemented on pilot projects as field demonstrations/case studies that could be utilized to understand relevant field processes, confirm assumptions, and further enhance previous LCA, BCA, and CE studies with real world data. Monitoring the field implementation of a CPSA can also provide insight into prevalent barriers and highlight externalities/opportunities that were not evident in theoretical evaluations. Lastly, successive field trials of individual CPSAs can provide opportunities to incorporate implementation lessons learned, evaluate work process formalization strategies, and develop specialized implementation tools that are adapted to the needs of the field personnel applying the CPSA.

Chapter Ten: Conclusion and Recommendations

Conclusions

This study of sustainability opportunities during construction was conducted to better understand the construction management decisions and actions that offer the greatest opportunities for sustainability impacts on projects, to demonstrate the effects of these strategies through applications, and to provide a more quantitative foundation for future decision-making and continuous advancement. Review of relevant sustainability publications revealed that advances in project level sustainability practices have primarily focused on the early Concept Planning and Design phases of capital projects. Although some published works on construction sustainability practices are available, this body of knowledge is still in its infancy and is highly fragmented and incomplete. A dearth of sustainability literature on construction phase actions suggests that higher levels of sustainability attention and effort are needed during the construction phase of capital projects.

In response, this research has identified 54 different actions that project teams can apply during construction to enhance the overall sustainability of their project. These CPSAs have been cataloged, characterized, and evaluated to facilitate their consideration and implementation by project teams. An accompanying CPSA screening tool was developed to further enable project teams to determine applicable CPSAs for their projects based on their project-specific sustainability priorities and compatible project characteristics.

This research effort has also produced both input- and output-oriented sustainability metrics for the construction phase of capital projects. For example, the CPSA Implementation Index is an input-oriented metric that can be used to measure and track the level of effort applied towards the implementation of targeted CPSAs. Conversely, a total of 59 output- and CPSA-oriented metrics have been tabulated.

A seven-step work process was also developed to provide additional guidance on how project teams can integrate CPSA selection/implementation and associated research tools within the framework of capital projects. Supplementary implementation guidance was prepared for three targeted CPSAs: #9 Paperless Communication and Construction Documentation; #28 Sustainable Temporary Facilities; and #30 Source of On-Site Power. Results from this in-depth examination offers project teams more insight into the benefits and details of CPSA implementation. Equipped with the findings from this research, owners and construction contractors will be better prepared to implement sustainability actions during the construction phase of capital projects.

Recommendations for Future Research

Based on research findings, it is recommended that the following construction-related sustainability research be performed in the future to further this body of knowledge:

- Pursue the development of CPSA application case studies, involving actual, detailed implementation with some emphasis placed on smaller, low-cost projects.
- Perform broad-based benchmarking of construction sustainability performance that is representative of the industry and CII member companies.
- Investigate and quantify the benefits that accrue from community social responsibility initiatives.
- Continue additional in-depth analysis of jobsite temporary power sources and associated impacts. This follow-on study should be supplemented by field trials to further support findings and implementation guidance.
- Develop smart-phone/tablet applications and/or web-based tools that support CPSA selection and implementation.

Appendices

Appendix A - Sample Research Team Background Assessment Form

RT304 Member Background Assessment

Version Date: January 10, 2013

NAME:			DATE:
COMPANY NAME:			
COMPANY TYPE: (CHECK ALL THAT APPLY)	☐ OWNER	☐ CONSTRUCTOR	☐ DESIGN CONSULTANT
	☐ EQUIPMENT AND MATERIAL SUPPLIER		☐ SUBCONTRACTOR
	☐ OTHER:		
# OF YEARS OF TOTAL INDUSTRY EXPERIENCE:			

PROJECT WORK EXPERIENCE: AVERAGE SIZE OF PROJECTS

AVERAGE PROJECT SIZE:	☐ <$10 mill	☐ $10 mill to $50 mill	☐ $50 mill to $200 mill	☐ $200 mill to $500 mill	☐ > $500 mill

Row %s should sum to 100%

________% US DOMESTIC PROJECTS	________% NON-US PROJECTS	Σ = 100%
________% PRIVATE PROJECTS	________% PUBLIC PROJECTS	Σ = 100%
________% RURAL SITES	________% URBAN SITES	Σ = 100%
________% FRONTIER/ REMOTE LOCATION	________% DEVELOPED LOCATION	Σ = 100%
________% GREENFIELD PROJECTS	________% BROWNFIELD PROJECTS	Σ = 100%
________% OPEN SHOP WORKFORCE	________% UNION WORKFORCE	Σ = 100%

% OF TIME SPENT IN EACH PROJECT PHASE (TOTAL = 100%)	________% FEASIBILITY	________% PROJECT CONCEPTS	________% FEED/DEFINE
	________% DETAILED DESIGN	________% PROCUREMENT	________% CONSTRUCTION
	________% COMMISSIONING	________% OPERATIONS	Other:

PROJECT WORK EXPERIENCE

SECTOR	SUB-SECTOR	
	AREA (CHECK ALL THAT APPLY)	% OF TOTAL YRS OF EXPERIENCE
INDUSTRIAL	☐ POWER GENERATION	
	☐ RENEWABLE ENERGY	
	☐ PETRO-CHEMICAL	
	☐ PHARMACEUTICAL	
	☐ CONSUMER PRODUCTS	
	☐ METALS MANUFACTURING	
	☐ ASSEMBLY PLANT/ FABRICATION YARD	
	☐ MINING	
	☐ DECOMMISSIONING	
	☐ OTHER:	
	☐ OTHER:	
INFRASTRUCTURE	☐ UNDERGROUND UTILITY (water, sewer, gas)	
	☐ ROADS (heavy highway, streets)	
	☐ TRANSIT	
	☐ LIGHT RAIL	
	☐ HEAVY RAIL	
	☐ BRIDGES	
	☐ POWER TRANSMISSION	
	☐ TELECOMMUNICATIONS	
	☐ DAMS, LEVEES	
	☐ CANALS	
	☐ TUNNELS	
	☐ AIRPORTS	
	☐ PORTS/MARINE	
	☐ OTHER:	
	☐ OTHER:	
COMMERCIAL	☐ MILITARY	
	☐ HEALTH CARE	
	☐ OFFICE BUILDING	
	☐ RETAIL/SHOPPING	
	☐ LABORATORIES	
	☐ DATA CENTERS	
	☐ SCHOOLS/UNIVERSITY	
	☐ SPORTS/ PERFORMING ARTS	
	☐ OTHER:	
	☐ OTHER:	

COLUMN $\Sigma = 100$

PLEASE LIST OR DESCRIBE ANY PROFESSIONAL SPECIALIZATIONS:

____

____

KNOWLEDGE ON SUSTAINABILITY IMPACTS/DRIVERS

CHECK ONLY AREAS WITH ADVANCE KNOWLEDGE [AK] OR WHERE YOU ARE DESIGNATED EXPERT [E]

ENVIRONMENTAL	AK	E	SOCIAL/COMMUNITY	AK	E	ECONOMIC	AK	E
ENERGY USE			COMMUNITY RELATIONSHIPS/ ENGAGEMENT			NET ECONOMIC IMPACT		
CLIMATE IMPACTS (GREENHOUSE GASES)			SAFE WORKING ENVIRONMENT			JOBS CREATED/PAYROLL IMPACT		
WASTE MANAGEMENT			CONSTRUCTION SAFETY			DEMAND ON LOCAL RESOURCES		
MATERIAL CONSUMPTION			WORKFORCE TRAINING			TAX REVENUE GENERATED		
WATER CONSUMPTION & QUALITY IMPAIRMENT			NOISE/VIBRATIONS			LOCAL ECONOMIC LEVERAGING		
CRITERIA AIR POLLUTANTS (NO_x, SO_x, PM)			ODORS			IN KIND CONTRIBUTIONS TO THE COMMUNITY		
LAND USE / HABITAT IMPACTS			LIGHT POLLUTION			OTHER:		
INDOOR AIR			HISTORICAL/CULTURAL IMPACTS			OTHER:		
OTHER:			IMPACTS TO EXISTING INFRASTRUCTURE			OTHER:		
OTHER:			CONSTRUCTION SITE RESTORATION			OTHER:		
OTHER:			TRAFFIC IMPACTS			OTHER:		
OTHER:			OTHER:			OTHER:		
OTHER:			OTHER:			OTHER:		

Appendix B - Sample CPSA Catalog Entry Template Form

A. CPSA NO.: Click here to enter text.

1. CPSA TITLE: Click here to enter text.	4. DATE: 4/15/2014
2. PRIMARY CONSTRUCTION FUNCTION: Click here to enter text.	
3. SECONDARY CONSTRUCTION FUNCTION: Click here to enter text.	

B. CPSA DESCRIPTION: (WHAT?, WHY?)

Click here to enter text.	Insert Image.

C. SUSTAINABILITY IMPACTS CHARACTERIZATION: (SELECT/CHECK ALL THAT APPLY)

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Choose an item.	Choose an item.	Choose an item.	☐	☐	☐	☐	☐
2. SOCIAL	Choose an item.	Choose an item.	Choose an item.	☐	☐	☐	☐	☐
3. ECONOMIC	Choose an item.	Choose an item.	Choose an item.	☐	☐	☐	☐	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA: (CHECK ALL THAT APPLY)

1. Project **safety** performance: ☐	3. Project **cost** performance: ☐	5. None: ☐
2. Project **quality** performance: ☐	4. Project **schedule** performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☐	3. Challenging: ☐

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	Click here to enter text.
2	Click here to enter text.
3	Click here to enter text.

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRIC(S):

1	Click here to enter text.
2	Click here to enter text.

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Click here to enter text.
2	Click here to enter text.

I. REFERENCE

1	Click here to enter text.
2	Click here to enter text.
3	Click here to enter text.
4	Click here to enter text.

Appendix C - Catalog of Construction Phase Sustainability Actions

A. CPSA NO.: 1

1. CPSA TITLE: Leadership Team Staffing for Sustainable Projects	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: Project Management	
3. SECONDARY CONSTRUCTION FUNCTION: None	

B. CPSA DESCRIPTION:

Seek to establish a "hearts and minds" sustainability-oriented culture much like organizations pursue a safety or quality culture. Employ administrative staff that possess skills and experience in the management of sustainable projects. Identify voids in knowledge and be prepared to offer supplemental training on project environmental and community impacts, worker safety cultures, effective project communication, etc.

Leadership Team

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Energy consumption	Waste generation	Water consumption	☐	☐	☐	☐	☒
2. SOCIAL	Health & safety	Skills development	Community relationships	☐	☐	☐	☐	☒
3. ECONOMIC	Project fiscal impacts	-	-	☐	☒	☐	☐	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project safety performance: ☒	3. Project cost performance: ☐	5. None: ☐
2. Project quality performance: ☐	4. Project schedule performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☐	3. Challenging: ☒

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	Project management has taken a lead role in endorsing sustainable solutions
2	Collaborative and communicative organization
3	The project team has experience incorporating sustainability provisions

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Percent of projects with Sustainability Performance section in project reports
2	Percent of projects that document sustainability lessons-learned

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Staff that are unaware of sustainability concepts
2	Sustainability is viewed as an "add-on", rather than an integrated aspect of the project

I. REFERENCES

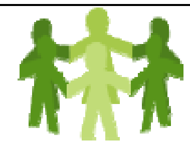
1	ACRP. (2012). *ACRP Report 80 - Guidebook for Incorporating Sustainability into Traditional Airport Projects* (pp. 1–103). Washington D.C.: Airport Cooperative Research Program.
2	Robichaud, L. B., & Anantatmula, V. S. (2011). Greening Project Management Practices for Sustainable Construction. *Journal of Management in Engineering*, *27*, 48–57.
3	Underwood, A. A. (2012). Lessons Learned: Implementing Context Sensitive and Sustainable Solutions on the Oregon State Bridge Delivery Program (pp. 384–391). Presented at the 2012 International Conference on Sustainable Design and Construction, Texas: American Society of Civil Engineers.

A. CPSA NO.: **2**

1. CPSA TITLE: Community Social Responsibility Program	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: Project Management	
3. SECONDARY CONSTRUCTION FUNCTION: None	

B. CPSA DESCRIPTION:

Consider establishing a formal community social responsibility program as a way to respond to stakeholder needs. Formal community signoffs on individual initiatives can be very beneficial. Related volunteer-based programs can have a significant impact as well. This responsibility program should include the development and maintenance of a project website for the local community and holding community forums to discuss project issues, such as traffic impacts and upcoming construction work.



C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Noise	Light pollution	Odors	☐	☐	☐	☒	☐
2. SOCIAL	Health & safety	Community relationships	Community infrastructure	☐	☐	☐	☐	☒
3. ECONOMIC	Project fiscal impacts	-	-	☐	☒	☐	☐	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project **safety** performance: ☒	3. Project **cost** performance: ☐	5. None: ☐
2. Project **quality** performance: ☐	4. Project **schedule** performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☒	3. Challenging: ☐

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	The project is large and complex
2	Project stakeholders and local community leaders are clearly defined and accessible
3	Community members have access to the Internet

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Percent of community issues addressed
2	Percentage of stakeholder engagement plan that is implemented

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Local community is not cohesive, so leadership is lacking
2	Community members do not wish to engage with project management

I. REFERENCES

1	Chasey, A. D., & Agrawal, N. (2012). A Case Study on the Social Aspect of Sustainability in Construction (pp. 543–551). Presented at the 2012 International Conference on Sustainable Design and Construction, Texas: American Society of Civil Engineers.
2	IPIECA. (2011). *Local Content Strategy: A guidance document for the oil and gas industry* (pp. 1–32). International Petroleum Industry Environmental and Conservation Association.
3	Peters, E., Clermont, S., Culberson, S. D., Unzelman, R., Venzon, C. L., Kloiber, A., ... Eastmon, A. (2011a). *ACRP Report 42 - Sustainable Airport Construction Practices* (pp. 1–221). Washington D.C.: Airport Cooperative Research Program.
4	Venner, M., & Zeimer, L. (2004). *Environmental Stewardship Practices, Procedures, and Policies for Highway Construction and Maintenance* (pp. 1–850). National Cooperative Highway Research Program.

A. CPSA NO.: 3

1. CPSA TITLE: Contractor Sustainability Program and Recognition System	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: Project Management	
3. SECONDARY CONSTRUCTION FUNCTION: None	

B. CPSA DESCRIPTION:

The project team and its subcontractors/suppliers should establish and implement a sustainability program with a recognition system that rewards innovation and effectiveness. Identify sustainability program responsibilities and performance expectations for key personnel. Provide rewards for sustainable performance that meets or exceeds program expectations. The reward program should address all three dimensions of sustainability.

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				– –	–	N	+	++
1. ENVIRONMENTAL	Energy consumption	Waste generation	Water consumption	☐	☐	☐	☒	☐
2. SOCIAL	Health & safety	Community relationships	-	☐	☐	☐	☒	☐
3. ECONOMIC	Negligible	-	-	☐	☐	☒	☐	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project safety performance: ☐	3. Project cost performance: ☐	5. None: ☒
2. Project quality performance: ☐	4. Project schedule performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☒	2. Moderate: ☐	3. Challenging: ☐

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	Project organization and/or sustainability program are large in size, scope, and/or effort
2	Team's sustainability effort is new, fledgling, or ill-structured
3	The project is located in an environmentally/socially-sensitive area

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Project-over-project or year-over-year comparison of one or more specific sustainability metrics
2	Number of annual awards for sustainability contributions

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Lack of support staffing, training, funding, and other needed sustainability program resources
2	Lack of team-level sustainability commitment and leadership

I. REFERENCES

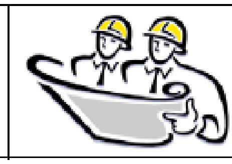
1	Azada, J., & Rochte, M. (2013). *Workforce for Good: Employee Engagement in CSR/Sustainability* (pp. 1–22). Workforce for Good.
2	Lallande, A. (2008, April). Awards & Incentives Agenda. *HR Magazine*, *53*(4). Retrieved from http://www.shrm.org/Publications/hrmagazine/EditorialContent/Pages/4Lallande-Awards%20and%20Incentives%20Agenda.aspx
3	NCCER. (2011). NCCER - Training & Certifications. *NCCER*. Retrieved February 13, 2014, from http://www.nccer.org/training-and-certifications
4	Peirce, M., & Madden, K. (2005). *Driving Success: Human resources and sustainable development* (pp. 1–20). WBCSD; CPI.

A. CPSA NO.: 4

1. CPSA TITLE: Sustainability Provisions in Construction Execution Plans	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: Project Management	
3. SECONDARY CONSTRUCTION FUNCTION: None	

B. CPSA DESCRIPTION:

Incorporate sustainability provisions and solutions in the construction execution plans similar to provisions for safety, quality, cost, schedule, and resource management, among others. Include a discussion on sustainability requirements and opportunities as part of the preconstruction/kick-off meeting agenda to align the project team on sustainability objectives and expectations. Confirm that the team understands any sustainability specifications and assigns responsibilities and commitments for documentation.



C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				– –	–	N	+	++
1. ENVIRONMENTAL	Energy consumption	Waste generation	Water consumption	☐	☐	☐	☒	☐
2. SOCIAL	Health & safety	Jobs created	Traffic	☐	☐	☐	☒	☐
3. ECONOMIC	Project fiscal impacts	-	-	☐	☐	☐	☒	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project safety performance: ☒	3. Project cost performance: ☒	5. None: ☐
2. Project quality performance: ☒	4. Project schedule performance: ☒	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☒	3. Challenging: ☐

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	Project management has taken a lead role in endorsing sustainability solutions
2	The project is large and complex
3	The project team has experience incorporating sustainability provisions

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Percent of projects with Sustainability Performance section in project reports
2	Contract requirement that sustainability be included in the project execution plan

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Unwillingness of project owner to incorporate sustainability provisions in the execution plan
2	Inexperience of staff to incorporate sustainability requirements into the execution plans

I. REFERENCES

1	Mendler, S. F., & Odell, W. (2000). *The HOK Guidebook to Sustainable Design*. New York: John Wiley & Sons, Inc.
2	Peters, E., Clermont, S., Culberson, S. D., Unzelman, R., Venzon, C. L., Kloiber, A., ... Eastmon, A. (2011a). *ACRP Report 42 - Sustainable Airport Construction Practices* (pp. 1–221). Washington D.C.: Airport Cooperative Research Program.
3	Varghese, J., & Webb, D. (2012). Contractor's Role During the Construction Phase. *Sustainable Construction Magazine*, (Winter 2012), 10–12.

A. CPSA NO.: 5

1. CPSA TITLE: Sustainability Risk Management	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: Project Management	
3. SECONDARY CONSTRUCTION FUNCTION: None	

B. CPSA DESCRIPTION:

Ensure that sustainability risks are incorporated into the project risk management process by addressing environmental, social, and economic threats and opportunities. Perform a sustainability risk assessment to identify sources and root causes of accidents, releases or spills of hazardous material (i.e. exposure to the worker, community, and environment), and cultural clashes, among other events. Record such events in a Risk Register. Mitigation measures should be developed and employed to minimize negative sustainability impacts.

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Energy consumption	Waste generation	Water consumption	☐	☐	☐	☒	☐
2. SOCIAL	Health & safety	Community relationships	-	☐	☐	☐	☒	☐
3. ECONOMIC	Project fiscal impacts	-	-	☐	☐	☐	☒	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project **safety** performance: ☐	3. Project **cost** performance: ☒	5. None: ☐
2. Project **quality** performance: ☐	4. Project **schedule** performance: ☒	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☐	3. Challenging: ☒

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	The project is located in an environmentally/socially-sensitive area
2	The project is large and complex
3	The project owner, stakeholders, and/or local community have diverse interests relative to sustainability

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Portion of sustainability risks that are effectively mitigated
2	Cost and/or schedule savings from sustainability risk avoidance or mitigation

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Non-alignment in the identification of sustainability risks
2	Failure to effectively mitigate an identified sustainability risk

I. REFERENCES

1	Diab, M. F. (2012). Integrating Risk Assessment in Planning for Sustainable Infrastructure Projects (pp. 350–358). Presented at the 2012 International Conference on Sustainable Design and Construction, Texas: American Society of Civil Engineers.
2	Nijpels, H. T. M. (1990). Sustainability Development and Risk Management. *Marine Policy*, *14*(4), 219–223.
3	Yilmaz, A. K., & Flouris, T. (2010). Managing corporate sustainability: Risk management process based perspective. *African Journal of Business Management*, *4*(2), 162–171.

A. CPSA NO.: 6

1. CPSA TITLE: Stakeholder Engagement Plan	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: Project Management	
3. SECONDARY CONSTRUCTION FUNCTION: None	

B. CPSA DESCRIPTION:

Lack of effective and timely stakeholder engagement can often lead to heightened sustainability-related risks. Formally assess and monitor the needs, interests, concerns, and expectations of external stakeholders that possess high interest and potentially high influence. Develop and implement an engagement plan for these stakeholders.

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Noise	Light pollution	Odors	☐	☐	☐	☒	☐
2. SOCIAL	Community relationships	Community infrastructure	Traffic	☐	☐	☐	☒	☐
3. ECONOMIC	Negligible	-	-	☐	☐	☒	☐	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project **safety** performance: ☐	3. Project **cost** performance: ☐	5. None: ☐
2. Project **quality** performance: ☐	4. Project **schedule** performance: ☒	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☐	3. Challenging: ☒

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	Project stakeholders and local community leaders are clearly defined and accessible
2	The project owner, stakeholders, and/or local community have diverse interests relative to sustainability
3	The project is large and complex

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Percent of community issues addressed
2	Percentage of stakeholder engagement plan that is implemented

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Stakeholders are difficult to identify
2	Stakeholders do not wish to participate in engagement opportunities

I. REFERENCES

1	Chasey, A. D., & Agrawal, N. (2012). A Case Study on the Social Aspect of Sustainability in Construction (pp. 543–551). Presented at the 2012 International Conference on Sustainable Design and Construction, Texas: American Society of Civil Engineers.
2	Robichaud, L. B., & Anantatmula, V. S. (2011). Greening Project Management Practices for Sustainable Construction. *Journal of Management in Engineering*, *27*, 48–57.

A. CPSA NO.: 7

1. CPSA TITLE: <u>Site Work Hour Schedule to Reduce Traffic Impacts</u>	4. DATE: 4/13/2014
2. PRIMARY CONSTRUCTION FUNCTION: <u>Project Management</u>	
3. SECONDARY CONSTRUCTION FUNCTION: <u>Field Engineering</u>	

B. CPSA DESCRIPTION:

Analyze traffic impacts for different site work hour schedules, particularly during rush hour periods. Consider limiting construction work hours to better accommodate traffic flow during rush hour periods. Also consider noise and light effects in establishing site work hours and truck delivery hours that are compatible with local community concerns.

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	–	N	+	++
1. ENVIRONMENTAL	Energy consumption	Greenhouse gases	Criteria air pollutants	☐	☐	☐	☒	☐
2. SOCIAL	Traffic	Health & safety	Community relationships	☐	☐	☐	☒	☐
3. ECONOMIC	Project fiscal impacts	-	-	☐	☒	☐	☐	☐

D. THIS CPSA HAS A <u>SIGNIFICANT POSITIVE</u> INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project <u>safety</u> performance: ☐	3. Project <u>cost</u> performance: ☐	5. None: ☒
2. Project <u>quality</u> performance: ☐	4. Project <u>schedule</u> performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☒	3. Challenging: ☐

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	The project schedule and budget are flexible
2	Sufficient resources are available to modify schedules
3	There is sufficient infrastructure to minimize traffic into and out of the site

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Periodic traffic counts on major arterials near the jobsite
2	Number of complaints from community, agency, or camp residents

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Schedule-driven project that requires work around the clock
2	There is insufficient infrastructure and/or budget such that it is difficult to get all materials needed within non-peak traffic times

I. REFERENCES

1	City of New York DDC. (1999). *High Performance Building Guidelines* (pp. 1–144). New York: City of New York Department of Design and Construction.
2	Strombom, C. (2007, December). Highway Sustainability Checklist Version 6. Parsons Brinckerhoff. Retrieved from http://www.environment.transportation.org/environmental_issues/sustainability/recent_dev_archive.aspx?year=2008#bookmarkPBsHighwaySustainabilityChecklistReceivesAward
3	Venner, M., & Zeimer, L. (2004). *Environmental Stewardship Practices, Procedures, and Policies for Highway Construction and Maintenance* (pp. 1–850). National Cooperative Highway Research Program.

A. CPSA NO.: 8

1. CPSA TITLE: Work Schedule to Reduce Electricity Impacts	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: Project Management	
3. SECONDARY CONSTRUCTION FUNCTION: None	

B. CPSA DESCRIPTION:

Modify the field work schedule to reduce electricity consumption and respective environmental impacts of electricity consumption. Schedule activities during the day to reduce electricity demands for lighting and coordinate electricity-intensive activities when energy sources used for electricity production have lower environmental impacts. For example, coal combustion is more environmentally intensive than natural gas which is more intensive than renewable resources.

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Energy consumption	Greenhouse gases	Criteria air pollutants	☐	☐	☐	☐	☒
2. SOCIAL	Negligible	-	-	☐	☐	☒	☐	☐
3. ECONOMIC	Negligible	-	-	☐	☐	☒	☐	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project **safety** performance: ☐	3. Project **cost** performance: ☐	5. None: ☒
2. Project **quality** performance: ☐	4. Project **schedule** performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☐	3. Challenging: ☒

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	The project schedule and budget are flexible
2	There are several options for providing electricity
3	Sufficient resources are available to modify schedules

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Percent of craft work hours performed in night shift
2	Percent of jobsite electricity from renewable sources

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Schedule-driven project that requires work around the clock
2	There are insufficient resources available and/or budget constraints to move work to nighttime hours

I. REFERENCES

1	Ko, J. (2010). *Carbon: Reducing the footprint of the construction process* (No. 6) (pp. 1–65). Strategic Forum for Construction and the Carbon Trust.
2	Siler-Evans, K., Azevedo, I. L., & Morgan, M. G. (2012). Marginal Emissions Factors for the U.S. Electricity System. *Environmental Science & Technology*, *46*, 4742–4748.
3	Strombom, C. (2007, December). Highway Sustainability Checklist Version 6. Parsons Brinckerhoff. Retrieved from http://www.environment.transportation.org/environmental_issues/sustainability/recent_dev_archive.aspx?year=2008#bookmarkPBsHighwaySustainabilityChecklistReceivesAward
4	Yates, J. K. (2009). *Sustainable Design and Construction for Industrial Construction: Implementation Resources* (Implementation Resource No. 250-3) (pp. 1–31). Construction Industry Institute.

A. CPSA NO.: 9

1. CPSA TITLE: <u>Paperless Communication and Construction Documentation</u>	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: <u>Project Management</u>	
3. SECONDARY CONSTRUCTION FUNCTION: <u>None</u>	

B. CPSA DESCRIPTION:

Replace hardcopy-based communications with electronic/digital forms wherever possible. Consider developing and implementing digital data collection systems and real-time field reporting technologies to electronically streamline traditional paper-based processes and further reduce the reliance on paper files, drawings, and other documents during construction. Adopting green meeting practices can further reduce negative sustainability impacts. Examples of eco-friendly meeting practices include distributing meeting materials electronically, arranging meetings via telephone or Internet to reduce travel, and encouraging carpools or public transportation when travel cannot be avoided. If printing is required, modify the default setting of the printer to print double-sided and encourage recycling of all documents.

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Energy consumption	Greenhouse gases	Waste generation	☐	☐	☐	☒	☐
2. SOCIAL	Negligible	-	-	☐	☐	☒	☐	☐
3. ECONOMIC	Project fiscal impacts	-	-	☐	☐	☐	☒	☐

D. THIS CPSA HAS A <u>SIGNIFICANT POSITIVE</u> INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project <u>safety</u> performance: ☐	3. Project <u>cost</u> performance: ☒	5. None: ☐
2. Project <u>quality</u> performance: ☒	4. Project <u>schedule</u> performance: ☒	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☒	3. Challenging: ☐

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	Projects where all parties have computers or tablets and knowledge of electronic systems
2	All parties are willing to use electronic communications and align on same electronic systems
3	Electronic programs / forms are available and individuals with expertise are available to run them

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Percent of project documentation managed electronically
2	Approximate number of hard copy documents (pages) transferred to owner at final handover

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Unwillingness of employees, contractors, vendors, and suppliers to use electronic communications
2	Using disparate electronic hardware and software among communicating parties

I. REFERENCES

1	CDA. (2009). *Sustainable Airport Manual* (Final Report No. version 1) (pp. 1–239). Chicago: Chicago Department of Aviation.
2	Coddington, G. (2012, May). Accomplishing a Paperless Jobsite: A First-Person Look at the Issues and Complexities Facing a Project Team as it Eliminates On-the-Job Waste. *EDC Magazine*, 48–53.
3	Dorgan, C. (2011). Managing Documents Through the Life of a Project Using Bluebeam PDF Revu. *McCarthy - Insights That Build*, 1–14.
4	Fiatech. (2012). *Real-time Field Reporting Using Smart Devices* (pp. 1–54). Austin, TX: Fiatech.

A. CPSA NO.: 10

1. CPSA TITLE: Construction Team Sustainability Performance Assessment	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: Project Management	
3. SECONDARY CONSTRUCTION FUNCTION: None	

B. CPSA DESCRIPTION:

Assess the sustainability performance of the construction management team during and after the completion of the project. Consider including a sustainability performance section within the construction progress report and in the close-out report that indicates sustainability goals, accomplishments, intermediate lessons learned, and recommendations/suggestions for additional improvements.

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Energy consumption	Waste generation	Water consumption	☐	☐	☐	☒	☐
2. SOCIAL	Health & safety	Community relationships	Skills development	☐	☐	☐	☒	☐
3. ECONOMIC	Negligible	-	-	☐	☐	☒	☐	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project **safety** performance: ☐	3. Project **cost** performance: ☐	5. None: ☒
2. Project **quality** performance: ☐	4. Project **schedule** performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☒	3. Challenging: ☐

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	Sustainability performance and resource data are available
2	The project team is interested in evaluating and improving sustainability performance
3	The project team is interested in including, or has already incorporated, sustainability requirements into the prime contract

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Percent of projects with Sustainability Performance section in project reports
2	Project-over-project or year-over-year comparison of one or more specific sustainability metrics

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Unwillingness by team to perform assessment
2	Difficulty collecting sustainability data

I. REFERENCES

1	CEEQUAL. (2008). *CEEQUAL Scheme Description and Assessment Process Handbook* (pp. 1–114). The Civil Engineering Environmental Quality Assessment and Awards Scheme.
2	Lallande, A. (2008, April). Awards & Incentives Agenda. *HR Magazine*, *53*(4). Retrieved from http://www.shrm.org/Publications/hrmagazine/EditorialContent/Pages/4Lallande-Awards%20and%20Incentives%20Agenda.aspx
3	Martin, D., Vinci, S., & Prows, D. (2013). *Green Globes for New Construction: Better Building Science for Better Results* (pp. 1–11). Marston design studio and Morrison Hershfield Corp.
4	USGBC. (2010). *LEED 2009 for New Construction and Major Renovations* (pp. 1–85). U.S. Green Building Council, Inc.

A. CPSA NO.: 11

1. CPSA TITLE: Verification of Sustainability Claims and Ratings	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: Contracting	
3. SECONDARY CONSTRUCTION FUNCTION: None	

B. CPSA DESCRIPTION:

Review the credibility of sustainability claims (such as certifications or comparative metrics) of vendors and suppliers to facilitate prequalification and/or selection. Consider developing a verification procedure that can be replicated as necessary.

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Energy consumption	Waste generation	Water consumption	☐	☐	☐	☒	☐
2. SOCIAL	Health & safety	Skills development	Community relationships	☐	☐	☐	☒	☐
3. ECONOMIC	Negligible	-	-	☐	☐	☒	☐	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project **safety** performance: ☐	3. Project **cost** performance: ☐	5. None: ☒
2. Project **quality** performance: ☐	4. Project **schedule** performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☐	3. Challenging: ☒

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	Projects with a significant number of suppliers and vendors who have certifications or could obtain certifications
2	Projects with a few large vendors and suppliers
3	Projects with mature suppliers and vendors

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Percent of corporate purchases that consider sustainability claims in the prequalification process
2	Percent of suppliers and vendors that have at least one sustainability certification

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Unwillingness of suppliers and/or vendors to provide supportive documentation
2	Inability of vendors and suppliers in developing countries to obtain certifications due to cost or knowledge

I. REFERENCES

1	Lu, Y., & Cui, Q. (2011). Sustainability Rating System for Construction Corporation: A Best Practice Review (pp. 1–18). Presented at the International Conference on Sustainable Design & Construction, Kansas City, Missouri.
2	Radzinski, T. (2010). *Valid Sustainability Claim or Greenwashing?: The Importance of Specificity in Third-Party Certifications* (pp. 1–4). GreenCircle Certified.
3	Robichaud, L. B., & Anantatmula, V. S. (2011). Greening Project Management Practices for Sustainable Construction. *Journal of Management in Engineering*, *27*, 48–57.
4	TerraChoice. (2009). *The Seven Sins of Greenwashing: Environmental Claims in Consumer Markets* (Summary Report: North America) (pp. 1–22). TerraChoice.

A. CPSA NO.: 12

1. CPSA TITLE: Sustainability-friendly Project Delivery Methods	4. DATE: 4/13/2014
2. PRIMARY CONSTRUCTION FUNCTION: Contracting	
3. SECONDARY CONSTRUCTION FUNCTION: Project Management	

B. CPSA DESCRIPTION:

The traditional linear project delivery methods and contract agreements can undermine sustainability objectives and cause rework later in the project. Owner, with the help of contractors, should identify ways in which conventional project delivery models could be more sustainability-friendly. Consider adopting integrated delivery models (e.g., manager-at-risk, design-build with performance-based fee incentives) to enhance collaboration between project stakeholders and encourage innovative sustainability solutions. Contractors should understand the sustainability-enhancing additions to the contract, review warranties/liabilities associated with the implementation of sustainable construction methods, and allocate risk and accountability fairly to stakeholders who can best control and mitigate those risks. Public-Private Partnerships (e.g. Build-Operate-Transfer) should be considered to further promote contractor interest in sustainability throughout the life cycle of the project.

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Negligible	-	-	☐	☐	☒	☐	☐
2. SOCIAL	Jobs created	Skills development	Community relationships	☐	☐	☐	☒	☐
3. ECONOMIC	Negligible	-	-	☐	☐	☒	☐	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project **safety** performance: ☐	3. Project **cost** performance: ☐	5. None: ☒
2. Project **quality** performance: ☐	4. Project **schedule** performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☒	3. Challenging: ☐

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	Alternative project delivery methods are available for the project
2	The owner and contractor agree to share benefits/savings from employing sustainable solutions
3	The project team is interested in including, or has already incorporated, sustainability requirements into the prime contract

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Sustainability objectives are stated in the prime contract
2	Sustainability change proposal clause (similar to Value Engineering) is included in the prime contract

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Lack of understanding by owner or contractors about innovative delivery methods
2	Unwillingness by owner or contractors to use non-traditional delivery methods

I. REFERENCES

1	Gormley, J. H. (2011). Construction Contracts for Sustainable Projects. *Sustainable Construction Magazine*, (Spring 2011), 11–12.
2	Robichaud, L. B., & Anantatmula, V. S. (2011). Greening Project Management Practices for Sustainable Construction. *Journal of Management in Engineering*, *27*, 48–57.
3	Syal, M. G., Mago, S., & Moody, D. (2007). Impacts of LEED-NC Credits on Contractors. *Journal of Architectural Engineering*, *13*(4), 174–179.

A. CPSA NO.: 13

1. CPSA TITLE: Contractor Prequalification Based on Safety and Sustainability Performance	4. DATE: 4/13/2014
2. PRIMARY CONSTRUCTION FUNCTION: Contracting	
3. SECONDARY CONSTRUCTION FUNCTION: Project Management	

B. CPSA DESCRIPTION:

Consider employing contractors and sub-contractors with sustainability experience and knowledge (e.g. LEED-accredited or Envision-certified staff). Routinely include safety performance in the prequalification of contractors, sub-contractors, and suppliers. Enhanced safety performance can have a major impact on the local community and on project economics. Extending the prequalification requirement to include environmental aspects of sustainability can positively impact the community and project economics as well.

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Energy consumption	Waste generation	Water consumption	☐	☐	☐	☒	☐
2. SOCIAL	Health & safety	Community relationships	-	☐	☐	☐	☒	☐
3. ECONOMIC	Project fiscal impacts	-	-	☐	☐	☐	☒	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project safety performance: ☒	3. Project cost performance: ☒	5. None: ☐
2. Project quality performance: ☐	4. Project schedule performance: ☒	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☒	3. Challenging: ☐

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	The project is large and complex
2	Sufficient number of contractors are available
3	The project owner, stakeholders, and/or local community have diverse interests relative to sustainability

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Contractor safety performance vs. target
2	Percent of project contracts that incorporate sustainability issues as a part of contractor prequalification

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Contractors in developing countries may not have the expertise or statistical basis to meet sustainability prequalification requirements
2	Project owner may not want to set a prequalification requirement

I. REFERENCES

1	Anderson, I. L. (2004). *Prime Contractor Prequalification and Performance Evaluation* (No. Report FHWA - SC-03-09) (pp. 1–75). Clemson University.
2	Jarrah, R. T., & Siddiqui, M. K. (2012). Sustainability: Opportunities and Challenges from a Construction Contractor's Perspective (pp. 601–608). Presented at the 2012 International Conference on Sustainable Design and Construction, Texas: American Society of Civil Engineers.
3	Potter, K. J., & Sanvido, V. (1995). Implementing a Design/Build Prequalification System. *Journal of Management Engineering*, *11*, 30–34.
4	Truitt, D. (2012, March). Best Practices - Contractor Prequalification. *Professional Safety*, *March 2012*, 34–35.

A. CPSA NO.: 14

1. CPSA TITLE: Promotion of Local Employment and Skills Development	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: Contracting	
3. SECONDARY CONSTRUCTION FUNCTION: None	

B. CPSA DESCRIPTION:

Use of participation targets for officially-established Small Business Enterprises (SBE), Women-owned Business Enterprises (WBE), and Minority Business Enterprises (MBE) can help in promoting local employment and local skills development.

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Negligible	-	-	☐	☐	☒	☐	☐
2. SOCIAL	Jobs created	Tax revenue produced	Skills development	☐	☐	☐	☐	☒
3. ECONOMIC	Project fiscal impacts	-	-	☐	☒	☐	☐	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project **safety** performance: ☐	3. Project **cost** performance: ☐	5. None: ☒
2. Project **quality** performance: ☐	4. Project **schedule** performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☒	3. Challenging: ☐

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	Work that can be identified to go to SBEs / WBEs / MBEs doesn't require specialized expertise that might not be locally available
2	Project for national companies that specify goals for local content
3	The project is large and complex

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	MBE/WBE/SBE contracts as a percent of all contracts
2	Dollar value of MBE/ WBE/SBEs contracts

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Structure not in place to identify MBEs / WBEs / SBEs
2	Political resistance to "set-asides" for minority involvement

I. REFERENCES

1	DFW. (2012). *Small Business Enterprise (SBE) - Minority and Women Business Enterprise (MWBE) Program Policy* (pp. 1–16). Dallas/Fort Worth International Airport
2	Klimley, A. W. (1997, June). Minority Business Partnerships: A Successful Past and Promising Future. *Black Enterprise*, *27*(11), 1–14.
3	RSA. (2002). *Minority and Women Business Enterprise: Good Faith Effort Plan* (pp. 1–13). Montgomery, Alabama: Retirement System of Alabama.

A. CPSA NO.: 15

1. CPSA TITLE: Sustainability Change Proposal Clause	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: Contracting	
3. SECONDARY CONSTRUCTION FUNCTION: None	

B. CPSA DESCRIPTION:

Consider incorporating a Sustainability Change Proposal clause in the contract similar to the Value Engineering Change Proposal clauses typically in use. Consider giving the contractor the economic savings, while the owner retains the environmental and social/community benefits.

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Energy consumption	Waste generation	Water consumption	☐	☐	☐	☒	☐
2. SOCIAL	Health & safety	Skills development	Community relationships	☐	☐	☐	☒	☐
3. ECONOMIC	Negligible	-	-	☐	☐	☒	☐	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project safety performance: ☐	3. Project cost performance: ☐	5. None: ☒
2. Project quality performance: ☐	4. Project schedule performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☒	2. Moderate: ☐	3. Challenging: ☐

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	The owner and contractor agree to share the benefits/savings from employing sustainability solutions
2	The project is large and complex
3	The project team is interested in including, or has already incorporated, sustainability requirements into the prime contract

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Sustainability change proposal clause (similar to Value Engineering) is included in the prime contract
2	Number of changes/substitutions to environmentally friendly materials

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Difficulty in assigning savings to a particular proposal
2	Contractor doesn't see significant gain to assign and budget resources to investigate, estimate, and submit proposals to owner

I. REFERENCES

1	CTDOT. (2009). *Value Engineering Program* (pp. 1–18). Connecticut Department of Transportation Bureau of Engineering and Construction - Office of Quality Assurance.
2	FHWA. (2011, April). FHWA - Value Engineering. *Federal Highway Administration - Value Engineering*. Retrieved February 13, 2014, from http://www.fhwa.dot.gov/ve/veabout.cfm
3	Mandelbaum, J., & Reed, D. L. (2006). *Value Engineering Change Proposals in Supplies or Services Contracts* (No. IDA Document D-3046) (pp. 1–36). Alexandria, Virginia: Institute for Defense Analysis.

A. CPSA NO.: 16

1. CPSA TITLE: Labor-intensive versus Equipment-intensive Approaches	4. DATE: 4/13/2014
2. PRIMARY CONSTRUCTION FUNCTION: Field Engineering	
3. SECONDARY CONSTRUCTION FUNCTION: Project Management	

B. CPSA DESCRIPTION:

Some international projects in remote regions are challenged with high local unemployment among an untrained, unproductive, and unsafe labor force. In these cases tradeoffs between equipment-intensive and labor-intensive approaches must be examined. Significant impacts from this decision pertain to safety, productivity, economics, local employment, skills training, local economy, imported labor accommodations, etc. The establishment of a local skills-training program with a subsequent ramp-up of local employment may offer a middle-ground, win-win solution with positive long-term effects.

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Negligible	-	-	☐	☐	☒	☐	☐
2. SOCIAL	Health & safety	Skills development	Jobs created	☐	☐	☐	☒	☐
3. ECONOMIC	Project fiscal impacts	-	-	☐	☐	☐	☒	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project safety performance: ☒	3. Project cost performance: ☒	5. None: ☐
2. Project quality performance: ☒	4. Project schedule performance: ☒	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☐	3. Challenging: ☒

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	The project has high local content requirements for materials and services
2	The project is suffering from low field craft productivity
3	Selection of construction methods involves many complex tradeoffs

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Change in local employment from project (percent or number)
2	Field productivity

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Technical construction skills of available labor force may be inadequate
2	Local political pressure for local content may be unrealistic, given the availability of local construction skills

I. REFERENCES

1	CIDP. (2002). *Best Practice Guide: Labour-Based Methods and Technologies for Employment Intensive Construction Works* (pp. 1–301). Department of Public Works: Construction Industry Development Programme.
2	Ng, S. T., Tang, Z., & Palaneeswaran, E. (2008). Factors contributing to the success of equipment-intensive subcontractors in construction. *International Journal of Project Management*, *27*, 736–744.
3	Quagraine, V. K., Brandenburg, S. G., & Beliveau, Y. J. (2009). Improving Labor-Based Road Rehabilitation in Ghana. *Journal of Management in Engineering*, *25*(2), 87–96.
4	Shen, Z., Jensen, W., Berryman, C., & Zhu, Y. (2011). Comparative Study of Activity-Based Construction Labor Productivity in the United States and China. *Journal of Management in Engineering*, *27*(2), 116–124.

A. CPSA NO.: 17

1. CPSA TITLE: Pre-assembly and Pre-fabrication of Construction Elements	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: Field Engineering	
3. SECONDARY CONSTRUCTION FUNCTION: None	

B. CPSA DESCRIPTION:

Evaluate the environmental and community impacts from different approaches to constructor-optional jobsite or near-jobsite pre-fabrication/pre-assembly/pre-coating. Consider issues such as fabrication site location, safety, local employment, reduction of scaffolding, work process productivity, and reduced waste generation. For example, applying coatings in a shop environment prior to final installation in order to avoid exposures and excess material use (i.e. painting the tops of beams and outside of purlins and girts prior to installation for items such as floor plates, siding, and roof decks). Additional attention to work protection may be required.

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Waste generation	Energy consumption	Greenhouse gases	☐	☐	☐	☒	☐
2. SOCIAL	Health & safety	Community infrastructure	-	☐	☐	☐	☒	☐
3. ECONOMIC	Project fiscal impacts	-	-	☐	☐	☐	☒	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project safety performance: ☒	3. Project cost performance: ☒	5. None: ☐
2. Project quality performance: ☒	4. Project schedule performance: ☒	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☒	3. Challenging: ☐

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	A stick-built approach would involve a significant amount of scaffolding
2	Regional labor safety performance is below expectations
3	The project site is small in size or congested

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Contractor safety performance vs. target
2	Portion or volume of total waste recycled or diverted from a landfill

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Limited availability of heavy lift equipment or other equipment to support pre-fabrication activities
2	Limited project resources for temporary infrastructure to support preassembly activity

I. REFERENCES

1	Calkins, M. (2009). *Materials for Sustainable Sites*. New Jersey: John Wiley & Sons, Inc.
2	CDA. (2009). *Sustainable Airport Manual* (Final Report No. version 1) (pp. 1–239). Chicago: Chicago Department of Aviation.
3	CII RT283. (2013). *Industrial Modularization: Five Solutions Elements* (Implementation Resource No. 283-2) (pp. 1–113). Austin, TX: Construction Industry Institute.
4	MBI. (2014). Why Build Modular? *Modular Building Institute - Changing the way the world builds*. Retrieved February 13, 2014, from http://www.modular.org/HtmlPage.aspx?name=why_modular
5	Mendler, S. F., & Odell, W. (2000). *The HOK Guidebook to Sustainable Design*. New York: John Wiley & Sons, Inc.

A. CPSA NO.: 18

1. CPSA TITLE: Sequence and Route Planning for Project Transport	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: Field Engineering	
3. SECONDARY CONSTRUCTION FUNCTION: None	

B. CPSA DESCRIPTION:

Offsite and onsite project transport quantities, modes, sequences, routes and other site logistic parameters should be rigorously analyzed prior to site mobilization for environmental/community effects and sustainability-enhancing opportunities. Considerations should include new traffic generated, driver/rider safety, timing of traffic, traffic-generated noise, traffic-generated emissions, roadway damage/maintenance, response to accidents/first responder impacts, neighborhood input, and transport or introduction of pests/invasive species, among others.

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Energy consumption	Greenhouse gases	Criteria air pollutants	☐	☐	☐	☒	☐
2. SOCIAL	Health & safety	Traffic	Community relationships	☐	☐	☐	☒	☐
3. ECONOMIC	Negligible	-	-	☐	☐	☒	☐	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project **safety** performance: ☒	3. Project **cost** performance: ☐	5. None: ☐
2. Project **quality** performance: ☐	4. Project **schedule** performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☐	3. Challenging: ☒

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	Project will generate a significant amount of transport traffic
2	The project is located in an area with significant traffic congestion
3	The project is located in an area with recognized air quality problems

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Proportion of delivery arrivals during peak traffic hours
2	Local air quality metrics

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Limited ability of the project team to receive after-hours deliveries (including limitations in storage areas)
2	Inability to plan/integrate jobsite deliveries in a manner that reduces the number of total deliveries

I. REFERENCES

1	Chasey, A. D., & Agrawal, N. (2012). A Case Study on the Social Aspect of Sustainability in Construction (pp. 543–551). Presented at the 2012 International Conference on Sustainable Design and Construction, Texas: American Society of Civil Engineers.
2	Peters, E., Clermont, S., Culberson, S. D., Unzelman, R., Venzon, C. L., Kloiber, A., ... Eastmon, A. (2011a). *ACRP Report 42 - Sustainable Airport Construction Practices* (pp. 1–221). Washington D.C.: Airport Cooperative Research Program.
3	Yates, J. K. (2009). *Sustainable Design and Construction for Industrial Construction: Implementation Resources* (Implementation Resource No. 250-3) (pp. 1–31). Construction Industry Institute.

A. CPSA NO.: 19

1. CPSA TITLE: Minimization of Project's Footprint of Disruption	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: Field Engineering	
3. SECONDARY CONSTRUCTION FUNCTION: Construction Equipment Management	

B. CPSA DESCRIPTION:

Avoid unnecessary damage to existing infrastructure and minimize the footprint of disruption associated with construction operations. Consider specifying and marking/flagging areas of the site that should be kept free of traffic, equipment, and storage and designate access routes and parking. Consider the selection of technology and grading methods that are as low-impact as possible and reduce damage to existing working surfaces. For example, the use of wheeled earthmoving equipment instead of tracked equipment can minimize pavement surface damage. A second example is the implementation of an interlocking "unimat" or similar system to stabilize and/or protect heavy lift haul roads.

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Land use	-	-	☐	☐	☐	☐	☒
2. SOCIAL	Community relationships	Local resource depletion	Community infrastructure	☐	☐	☐	☒	☐
3. ECONOMIC	Negligible	-	-	☐	☐	☒	☐	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project safety performance: ☐	3. Project cost performance: ☐	5. None: ☒
2. Project quality performance: ☐	4. Project schedule performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☒	3. Challenging: ☐

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	The contractor has experience implementing sustainable solutions/practices
2	Alternative construction equipment is available in sizes sufficient to support construction activities
3	The project is located in an environmentally/socially-sensitive area

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Proportion of sensitive vegetation not impacted from project
2	Number of significant trees impacted from project

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Less disruptive equipment is not available
2	Workers' awareness of environmental destruction is minimal

I. REFERENCES

1	Kibert, C. J. (2008). Chapter 11 - Construction Operations. In *Sustainable Construction: Green Building Design and Delivery* (Second Edition., pp. 309–316). New Jersey: John Wiley & Sons, Inc.
2	Peters, E., Clermont, S., Culberson, S. D., Unzelman, R., Venzon, C. L., Kloiber, A., ... Eastmon, A. (2011a). *ACRP Report 42 - Sustainable Airport Construction Practices* (pp. 1–221). Washington D.C.: Airport Cooperative Research Program.
3	Venner, M., & Zeimer, L. (2004). *Environmental Stewardship Practices, Procedures, and Policies for Highway Construction and Maintenance* (pp. 1–850). National Cooperative Highway Research Program.

A. CPSA NO.: 20

1. CPSA TITLE: Sustainable Material Substitutions	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: Field Engineering	
3. SECONDARY CONSTRUCTION FUNCTION: None	

B. CPSA DESCRIPTION:

Review material substitutions (where contractually allowable and beneficial) and be aware of sustainability-friendly substitution options. For example, fly ash may be used as a cement substitute for non-structural concrete. In addition, encourage the use of materials that have high recycled content (metal structures, fencing, traffic barricades/cones, etc.), low-emitting/VOC-free (i.e. adhesives/sealants, paints/coatings, flooring systems, and composite wood/agrifiber products), FSC-certified wood products, and manufactured using rapidly renewable resources (plant-based cladding and insulation, linoleum flooring).

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Energy consumption	Greenhouse gases	Waste generation	☐	☐	☐	☒	☐
2. SOCIAL	Negligible	-	-	☐	☐	☒	☐	☐
3. ECONOMIC	Negligible	-	-	☐	☐	☒	☐	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project **safety** performance: ☐	3. Project **cost** performance: ☐	5. None: ☒
2. Project **quality** performance: ☐	4. Project **schedule** performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☒	3. Challenging: ☐

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	Project contract provides some flexibility for contractor material substitutions
2	Project contract provides an incentive for contractor-proposed cost-reducing changes (such as a Value Engineering Change clause)
3	The contractor has experience implementing sustainable solutions/practices

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Size of carbon footprint from project
2	Number of changes/substitutions to environmentally friendly materials

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Lack of contractor awareness of sustainability-friendly material substitution options
2	Lack of incentives for contractors to identify/recommend sustainability-friendly material substitutions

I. REFERENCES

1	ACRP. (2012). *ACRP Report 80 - Guidebook for Incorporating Sustainability into Traditional Airport Projects* (pp. 1–103). Washington D.C.: Airport Cooperative Research Program.
2	City of New York DDC. (1999). *High Performance Building Guidelines* (pp. 1–144). New York: City of New York Department of Design and Construction.
3	Stain, L., Wilson, A., & Malin, N. (2002). *GreenSpec Directory: Product Directory with Guideline Specifications* (Third edition.). Vermont: Building Green, Inc.
4	USGBC. (2010). *LEED 2009 for New Construction and Major Renovations* (pp. 1–85). U.S. Green Building Council, Inc.

A. CPSA NO.: 21

1. CPSA TITLE: Construction Noise/Vibration Abatement and Mitigation	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: Field Engineering	
3. SECONDARY CONSTRUCTION FUNCTION: Site Facilities & Operations	

B. CPSA DESCRIPTION:

Consider developing and implementing noise/vibration abatement and mitigation procedures. Identify site-specific mechanical/operational elements that are primary sources of these disturbances and assess their impacts on sensitive areas adjacent to the project site. If adjacent to a residential neighborhood, consider establishing no-work/no-noise time periods in mornings and evenings. If possible, consider relocating the source of disruption or configuring the construction site so as to minimize impacts. For example, site access may be designed so that delivery and haul trucks move through the site in one direction or in a loop without the need to back-up. Consider the deployment of noise/vibration reduction technologies (such as portable noise barriers, shrouds, intake/ exhaust mufflers, rubber-tire equipment, or noise-deadening material).

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Noise	-	-	☐	☐	☐	☒	☐
2. SOCIAL	Community relationships	-	-	☐	☐	☐	☒	☐
3. ECONOMIC	Project fiscal impacts	-	-	☐	☒	☐	☐	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project safety performance: ☐	3. Project cost performance: ☐	5. None: ☒
2. Project quality performance: ☐	4. Project schedule performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☒	3. Challenging: ☐

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	Construction activities will cause a significant amount of noise and/or vibration for a lengthy duration of time
2	Many neighbors adjacent to the jobsite are sensitive to the noise and/or vibration caused by the project
3	The project involves a significant amount of pile-driving, rock hammering, or blasting

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Reduction in measured noise level
2	Number of complaints from community, agency, or camp residents

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Difficulty in predicting the significance of construction noise/vibration, and its effect on the local community
2	Lack of awareness of mitigation measures that could reduce noise and/or vibration effects

I. REFERENCES

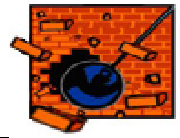
1	ACRP. (2012). *ACRP Report 80 - Guidebook for Incorporating Sustainability into Traditional Airport Projects* (pp. 1–103). Washington D.C.: Airport Cooperative Research Program.
2	City of New York DDC. (1999). *High Performance Building Guidelines* (pp. 1–144). New York: City of New York Department of Design and Construction.
3	Venner, M., & Zeimer, L. (2004). *Environmental Stewardship Practices, Procedures, and Policies for Highway Construction and Maintenance* (pp. 1–850). National Cooperative Highway Research Program.

A. CPSA NO.: 22

1. CPSA TITLE: Selective Demolition versus Conventional Demolition	4. DATE: 4/13/2014
2. PRIMARY CONSTRUCTION FUNCTION: Field Engineering	
3. SECONDARY CONSTRUCTION FUNCTION: Site Facilities & Operations	

B. CPSA DESCRIPTION:

Analyze the impacts of selective demolition as an alternative to conventional demolition methods. Consider the implications of sending mixed recyclables to a recycling center versus onsite sorting of recyclable materials.



C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Waste generation	Land use	-	☐	☐	☐	☐	☒
2. SOCIAL	Health & safety	Community infrastructure	-	☐	☐	☐	☒	☐
3. ECONOMIC	Project fiscal impacts	-	-	☐	☐	☐	☒	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project safety performance: ☐	3. Project cost performance: ☒	5. None: ☐
2. Project quality performance: ☐	4. Project schedule performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☒	3. Challenging: ☐

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	The project involves a significant amount of demolition
2	Project schedule allows time for selective demolition activity
3	Local recycling infrastructure is in place

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Portion or volume of total waste recycled or diverted from a landfill
2	Street value of recycled material

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Project schedule pressure requires an accelerated approach to demolition
2	Local area has no recycling infrastructure/community in place

I. REFERENCES

1	3D/International. (2000). *Construction and Demolition Waste Management Pocket Guide* (pp. 1–26). USA: HQ Air Force Center for Environmental Excellence.
2	Kourmpanis, B., Papadopoulos, A., Moustakas, K., Stylianou, M., Haralambous, K. J., & Loizidou, M. (2008). Preliminary Study for Management of Construction and Demolition Waste. *Waste Management and Research 2008, 26*(3), 267–275.
3	Napier, T. (2011, January). Construction Waste Management. *Whole Building Design Guide*. Retrieved July 6, 2011, from http://www.wbdg.org/resources/cwmgmt.php
4	U.S. Army Corps of Engineers. (2003). *Guidance for the Reduction of Demolition Waste through Reuse and Recycling* (Public Works Technical Bulletin No. 200-1-23) (pp. 1–160). Department of the Army.

A. CPSA NO.: 23

1. CPSA TITLE: Sustainable Large-scale Earthwork and Grading Operations	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: Field Engineering	
3. SECONDARY CONSTRUCTION FUNCTION: Materials Management	

B. CPSA DESCRIPTION:

Employ a balanced earthwork strategy that minimizes the transportation/placement of excavated soils at off-site locations. Thoroughly evaluate cut and fill requirements to determine the most suitable mix of resources/work sequences and identify opportunities to reuse excavated soils (i.e. on-site or on nearby properties/concurrent projects). Consider further improving grading operations by utilizing GPS technologies in lieu of conventional staking methods to perform soil volume checks, reduce rework, and improve overall operational efficiency (i.e. less surveying support, faster response to changes, and decrease in the number of passes required by earthmoving equipment).

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Energy consumption	Greenhouse gases	Waste generation	☐	☐	☐	☒	☐
2. SOCIAL	Health & safety	Community infrastructure	-	☐	☐	☐	☒	☐
3. ECONOMIC	Project fiscal impacts	-	-	☐	☐	☐	☒	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project safety performance: ☐	3. Project cost performance: ☒	5. None: ☐
2. Project quality performance: ☐	4. Project schedule performance: ☒	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☐	3. Challenging: ☒

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	Project execution involves large-scale earthwork and grading operations
2	The project is located in an area with recognized air quality problems
3	Adjacent project neighbors are very sensitive to project-generated noise, dust, and/or equipment exhaust

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Earthwork quantity reduced or eliminated
2	Equipment environmental performance

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Project design and/or contract hinders the contractor's ability to adjust earthwork quantities or placement locations
2	Contractor field engineer is not familiar with methods/technologies for enhancing earthwork efficiency

I. REFERENCES

1	CII RT250. (2011). *Sustainable Design and Construction for Industrial Construction: A Primer* (Implementation Resource No. 250-2) (pp. 1–85). Construction Industry Institute.
2	Han, S., Lee, S., Hong, T., & Chang, H. (2006). Simulation analysis of productivity variation by global positioning systems (GPS) implementation in earthmoving operations. *Canadian Journal of Civil Engineering*, *33*, 1105–1114.
3	Shehata, M. M., Khalek, H. A., & Hakam, M. A. (2012). Simulation Analysis for Productivity and Unit Cost by Implementing GPS Machine Guidance in Road Construction Operation in Egypt (pp. 642–653). Presented at the 2012 International Conference on Sustainable Design and Construction, Texas: American Society of Civil Engineers.
4	Venner, M., & Zeimer, L. (2004). *Environmental Stewardship Practices, Procedures, and Policies for Highway Construction and Maintenance* (pp. 1–850). National Cooperative Highway Research Program.

A. CPSA NO.: 24

1. CPSA TITLE: Reduction of Dunnage for Equipment Operations	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: Field Engineering	
3. SECONDARY CONSTRUCTION FUNCTION: Site Facilities & Operations	

B. CPSA DESCRIPTION:

Consider methods to reduce/re-use/minimize the need for "dunnage" as support base material for construction equipment.

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Waste generation	Land use	-	☐	☐	☐	☒	☐
2. SOCIAL	Negligible	-	-	☐	☐	☒	☐	☐
3. ECONOMIC	Negligible	-	-	☐	☐	☒	☐	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project safety performance: ☐	3. Project cost performance: ☐	5. None: ☒
2. Project quality performance: ☐	4. Project schedule performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☒	3. Challenging: ☐

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	Project involves extensive use of non-mobile heavy cranes
2	Project involves a substantial amount of dunnage for temporary support of construction equipment (such as cranes)
3	Project site is large in size

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Portion or volume of total waste recycled or diverted from a landfill
2	Street value of recycled material

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Inadequate information available on amount of dunnage already generated
2	Project needs for dunnage are difficult to predict

I. REFERENCES

1	Ratay, R. T. (1996). *Handbook of Temporary Structures in Construction*. New York: McGraw-Hill.
2	Rossnagel, W. E., Higgins, L. R., & MacDonald, J. A. (2009). *Handbook of Rigging*. New York: McGraw-Hill.

A. CPSA NO.: 25

1. CPSA TITLE: Reusable Shoring, Formwork, and Scaffolding	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: Field Engineering	
3. SECONDARY CONSTRUCTION FUNCTION: None	

B. CPSA DESCRIPTION:

When their use is unavoidable, consider the economic and sustainability benefits associated with durable, reusable, shoring, formwork, and scaffolding systems.

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Waste generation	-	-	☐	☐	☐	☒	☐
2. SOCIAL	Negligible	-	-	☐	☐	☒	☐	☐
3. ECONOMIC	Project fiscal impacts	-	-	☐	☐	☐	☒	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project safety performance: ☐	3. Project cost performance: ☒	5. None: ☐
2. Project quality performance: ☐	4. Project schedule performance: ☒	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☒	2. Moderate: ☐	3. Challenging: ☐

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	Project involves a substantial amount of shoring, formwork, and/or scaffolding
2	Project design entails a substantial amount of repetition or modularity, thereby leveraging standardization of shoring, formwork, and/or scaffolding
3	Future projects by this contractor will very likely entail shoring, formwork, and/or scaffolding

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Cost savings
2	Portion or volume of total waste recycled or diverted from a landfill

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Project design is not compatible with modular dimensions of shoring, formwork, and/or scaffolding
2	Labor unions and/or local content policies promote use of custom shoring, formwork, and/or scaffolding

I. REFERENCES

1	Calkins, M. (2009). *Materials for Sustainable Sites*. New Jersey: John Wiley & Sons, Inc.
2	Peters, E., Clermont, S., Culberson, S. D., Unzelman, R., Venzon, C. L., Kloiber, A., ... Eastmon, A. (2011a). *ACRP Report 42 - Sustainable Airport Construction Practices* (pp. 1–221). Washington D.C.: Airport Cooperative Research Program.
3	Stain, L., Wilson, A., & Malin, N. (2002). *GreenSpec Directory: Product Directory with Guideline Specifications* (Third edition.). Vermont: Building Green, Inc.

A. CPSA NO.: 26

1. CPSA TITLE: Protection of Cultural Artifacts and Endangered Species	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: Site Facilities & Operations	
3. SECONDARY CONSTRUCTION FUNCTION: Field Engineering	

B. CPSA DESCRIPTION:

Plan to protect cultural/historical artifacts and/or endangered species, if their presence is suspected or possible, and develop a recovery process/response plan in the event that such unexpected encounters occur during construction. Prior to mobilization, identify, document, and prioritize the site's natural and cultural attributes that are to be protected, conserved, or restored. Install construction fencing or flagging to protect these sensitive areas from encroachment by construction activities.

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE --	-	N	+	++
1. ENVIRONMENTAL	Land use	-	-	☐	☐	☐	☒	☐
2. SOCIAL	Community relationships	Local resource depletion	-	☐	☐	☐	☐	☒
3. ECONOMIC	Project fiscal impacts	-	-	☐	☒	☐	☐	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project safety performance: ☐	3. Project cost performance: ☐	5. None: ☐
2. Project quality performance: ☐	4. Project schedule performance: ☒	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☒	3. Challenging: ☐

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	Project region has a significant archeological history
2	Project region has some endangered species
3	The project is schedule-critical

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Portion of sustainability risks that are effectively mitigated
2	Time impact on project schedule

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Lack of awareness of history of the region (relative to archeology and endangered species)
2	Limited ability for preventive- and contingency planning

I. REFERENCES

1	City of New York DDC. (1999). *High Performance Building Guidelines* (pp. 1–144). New York: City of New York Department of Design and Construction.
2	Kibert, C. J. (2008). Chapter 11 - Construction Operations. In *Sustainable Construction: Green Building Design and Delivery* (Second Edition., pp. 309–316). New Jersey: John Wiley & Sons, Inc.
3	Venner, M., & Zeimer, L. (2004). *Environmental Stewardship Practices, Procedures, and Policies for Highway Construction and Maintenance* (pp. 1–850). National Cooperative Highway Research Program.

A. CPSA NO.: 27

1. CPSA TITLE: Protection of Trees and Vegetation	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: Site Facilities & Operations	
3. SECONDARY CONSTRUCTION FUNCTION: None	

B. CPSA DESCRIPTION:

Consider developing a tree and vegetation protection plan to reduce environmental impacts on existing ecosystems. Designate (i.e. flag, mark, fence) site-sensitive areas where staging, stockpiling, and soil compaction is prohibited. Identify and mark trees that must be cut/removed vs. trees that should remain and be protected. Install temporary barriers around protected trees, plants, and root zones that are in close proximity to construction/storage/transport activities.

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	–	N	+	++
1. ENVIRONMENTAL	Land use	-	-	☐	☐	☐	☒	☐
2. SOCIAL	Community relationships	Local resource depletion	-	☐	☐	☐	☒	☐
3. ECONOMIC	Negligible	-	-	☐	☐	☒	☐	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project safety performance: ☐	3. Project cost performance: ☐	5. None: ☒
2. Project quality performance: ☐	4. Project schedule performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☒	2. Moderate: ☐	3. Challenging: ☐

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	Project site includes existing trees and vegetation to be protected
2	Site congestion could result in damage to existing trees/vegetation
3	The project is located in an environmentally/socially-sensitive area

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Proportion of sensitive vegetation not impacted from project
2	Number of significant trees impacted from project

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Limited project resources to develop and implement plan
2	Inadequate information to gauge community's feelings toward potentially affected trees/vegetation

I. REFERENCES

1	City of New York DDC. (1999). *High Performance Building Guidelines* (pp. 1–144). New York: City of New York Department of Design and Construction.
2	Kibert, C. J. (2008). Chapter 11 - Construction Operations. In *Sustainable Construction: Green Building Design and Delivery* (Second Edition., pp. 309–316). New Jersey: John Wiley & Sons, Inc.
3	U.S. DE. (2008). *High Performance and Sustainable Buildings Implementation Plan* (pp. 1–47). U.S. Department of Energy.
4	Venner, M., & Zeimer, L. (2004). *Environmental Stewardship Practices, Procedures, and Policies for Highway Construction and Maintenance* (pp. 1–850). National Cooperative Highway Research Program.

A. CPSA NO.: 28

1. CPSA TITLE: Sustainable Temporary Facilities	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: Site Facilities & Operations	
3. SECONDARY CONSTRUCTION FUNCTION: Field Engineering	

B. CPSA DESCRIPTION:

Optimize the planning of temporary site facilities. Consider the sustainability impacts related to the scoping, sizing, location, and layout of: staging areas, laydown areas, material storage, fabrication shops, stockpiles, borrow pits, fuel storage, refueling stations, tool storage, parking lots, field offices, dining/ break facilities, toilet facilities, vertical transportation, storm drainage, temporary power generation, site lighting, and infrastructure tie-ins, etc. Consider both mobile/temporary and semi-permanent options. Consider related impacts from any separate, remote locations. Also evaluate the related special challenges and opportunities associated with projects located in dense urban areas or extremely remote rural areas, such as cell tower communications capacity, among others. Consider the implications of sequencing temporary facilities and construction site aesthetics for some projects. **SEE CHECKLIST TOOL**

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Energy consumption	Greenhouse gases	Waste generation	☐	☐	☐	☐	☒
2. SOCIAL	Health & safety	Local resource depletion	Community infrastructure	☐	☐	☐	☒	☐
3. ECONOMIC	Project fiscal impacts	-	-	☐	☐	☐	☒	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project safety performance: ☒	3. Project cost performance: ☒	5. None: ☐
2. Project quality performance: ☐	4. Project schedule performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☒	3. Challenging: ☐

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	The project is large and complex
2	Project involves a worker camp
3	The project is located in an environmentally/socially-sensitive area

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Size of carbon footprint from project
2	Proportion of sensitive vegetation not impacted from project

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Inadequate information to identify sustainability impacts of temporary site facilities
2	Limited project resources - first-cost often trumps any consideration of sustainability

I. REFERENCES

1	CDA. (2009). *Sustainable Airport Manual* (Final Report No. version 1) (pp. 1–239). Chicago: Chicago Department of Aviation.
2	CII RT250. (2011). *Sustainable Design and Construction for Industrial Construction: A Primer* (Implementation Resource No. 250-2) (pp. 1–85). Construction Industry Institute.
3	City of New York DDC. (1999). *High Performance Building Guidelines* (pp. 1–144). New York: City of New York Department of Design and Construction.
4	Hageman, K. (2013). Let There Be Light - Light Tower Lamp Options: What Sustainable Contractors Should Know. *Sustainable Construction Magazine*, (Spring 2013), 21–23.

A. CPSA NO.: 29

1. CPSA TITLE: <u>Sustainable Temporary Worker Camps</u>	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: <u>Site Facilities & Operations</u>	
3. SECONDARY CONSTRUCTION FUNCTION: <u>Project Management</u>	

B. CPSA DESCRIPTION:

Environmental and community impacts must be considered when planning for a temporary worker camp. Living community issues pertain to sizing, layout, and construction of medical/community health facilities, kitchen and dining facilities, sanitation facilities, waste management, along with operational system issues pertaining to community governance, transport and traffic, language, security, culture and religion, food options, and entertainment, among others. Plus, consider the decisions and associated sustainability impacts related to busing workers to and from the camp.

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				– –	–	N	+	++
1. ENVIRONMENTAL	Energy consumption	Greenhouse gases	Waste generation	☐	☐	☐	☒	☐
2. SOCIAL	Health & safety	Community relationships	Traffic	☐	☐	☐	☐	☒
3. ECONOMIC	Project fiscal impacts	-	-	☐	☐	☐	☒	☐

D. THIS CPSA HAS A <u>SIGNIFICANT POSITIVE</u> INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project <u>safety</u> performance: ☒	3. Project <u>cost</u> performance: ☒	5. None: ☐
2. Project <u>quality</u> performance: ☐	4. Project <u>schedule</u> performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☐	3. Challenging: ☒

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	Project size is very large relative to the local labor supply
2	Local labor supply is extremely limited
3	The project will have a culturally diverse workforce

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Level of satisfaction of workers living in project camp
2	Effort or resources required to reach employment targets (per hired craft worker or PM staff)

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Late and/or inadequate resource assessment of existing housing/community infrastructure, as the first step in defining craft housing needs
2	Lack of formal planning for camp services and facilities, including utilities, transportation, recreation, laundry, etc.

I. REFERENCES

1	EBRD & IFC. (2009). *Workers' accommodation: processes and standards* (pp. 1–35). European Bank for Reconstruction and Development and International Finance Corporation.
2	Franks, D. (2012). *Social impact assessment of resource projects* (No. 3) (pp. 1–15). Australia: International Mining for Development Centre.
3	Sulzberger, A. G. (2011, November). Oil Rigs Bring Camps of Men to the Prairie. *The New York Times: U.S.* Retrieved February 13, 2014, from http://www.nytimes.com/2011/11/26/us/north-dakota-oil-boom-creates-camps-of-men.html?pagewanted=1&_r=1&
4	Wanjek, C. (2013). *Workforce Housing and Feeding Solutions for Health, Safety, Productivity and Morale* (White Paper) (pp. 1–9). Target Logistics.

A. CPSA NO.: 30

1. CPSA TITLE: Source of On-site Power	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: Site Facilities & Operations	
3. SECONDARY CONSTRUCTION FUNCTION: Construction Equipment Management	

B. CPSA DESCRIPTION:

Consider the economic and environmental implications of different optional power and fuel sources (ultra-low sulfur diesel, biodiesel, LPG, LNG, CNG, solar PV, etc.) particularly in areas where the environmental impacts of grid electricity are relatively high. Seek to broaden the spectrum of possibilities by evaluating the generation of temporary power on-site vs. drawing power from the existing grid. When reviewing temporary on-site power generation, consider alternative solutions such as diesel engine emission/PM reducing retrofits, hybrid-diesel generators (battery-diesel, battery-PV-diesel, etc.), portable fuel cell generators, and micro-grid/smart-grid technologies (i.e. a sophisticated/intelligent power management system that can effectively link and control the operation of multiple power generators).

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				– –	–	N	+	++
1. ENVIRONMENTAL	Energy consumption	Greenhouse gases	Noise	☐	☐	☐	☒	☐
2. SOCIAL	Negligible	-	-	☐	☐	☒	☐	☐
3. ECONOMIC	Negligible	-	-	☐	☐	☒	☐	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project safety performance: ☐	3. Project cost performance: ☐	5. None: ☒
2. Project quality performance: ☐	4. Project schedule performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☐	3. Challenging: ☒

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	Regional energy costs are high and/or local grid-source power has significant negative environmental impacts
2	Project execution requires a significant amount of electrical power
3	Project is very distant from the local power grid

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Size of carbon footprint from project
2	Amount of particulate matter from site power sources

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Limited project resources to allow optional power sources to be researched
2	Inadequate technical support/information to decide on alternative power generation technologies

I. REFERENCES

1	Kusakana, K., & Vermaak, H. J. (2013). Hybrid Diesel Generator - Battery Systems for Off-Grid Rural Applications (pp. 839–844). Presented at the 2013 IEEE International Conference on Industrial Technology (ICIT), Institute of Electrical and Electronics Engineers.
2	Scanlon, B. (2013). The Power of Propane: Contractors complement eco-friendly building with alternative equipment on the jobsite. *Sustainable Construction Magazine*, (Summer 2013), 10–13.
3	U.S. DE. (2013). Alternative Fuels Data Center. *U.S. Department of Energy - Energy Efficiency & Renewable Energy*. Retrieved September 14, 2013, from http://www.afdc.energy.gov/
4	U.S. EPA. (2013, January). National Clean Diesel Campaign (NCDC) - Technologies Overview. *U.S. Environmental Protection Agency*. Retrieved September 18, 2013, from http://www.epa.gov/cleandiesel/technologies/index.htm
5	Venner, M., & Zeimer, L. (2004). *Environmental Stewardship Practices, Procedures, and Policies for Highway Construction and Maintenance* (pp. 1–850). National Cooperative Highway Research Program.

A. CPSA NO.: 31

1. CPSA TITLE: Site Energy Management	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: Site Facilities & Operations	
3. SECONDARY CONSTRUCTION FUNCTION: None	

B. CPSA DESCRIPTION:

Optimize management of site energy used in temporary facilities (such as project offices, fabrication shops, storage warehouses, and worker camps) by implementing computerized system control technologies (such as motion sensors for lights, site lighting, and HVAC control systems) and associated energy-reduction strategies. Manage phantom power consumption (by computers, printers, HVAC, and lighting, etc.) to further reduce the consumption of energy during periods of facility inactivity.

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Energy consumption	Greenhouse gases	Light pollution	☐	☐	☐	☒	☐
2. SOCIAL	Negligible	-	-	☐	☐	☒	☐	☐
3. ECONOMIC	Project fiscal impacts	-	-	☐	☐	☐	☒	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project safety performance: ☐	3. Project cost performance: ☒	5. None: ☐
2. Project quality performance: ☐	4. Project schedule performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☐	3. Challenging: ☒

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	An energy management system has not yet been implemented on the project
2	Workplace culture has not yet focused on energy efficiency
3	Regional energy costs are high and/or local grid-sourced power has significance negative environmental impacts

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Size of carbon footprint from project
2	Power consumption per basis unit ($K of construction, K work hours, etc.)

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	First-cost of system investment will deter many
2	System needs to be customized to unique working needs and characteristics of project team

I. REFERENCES

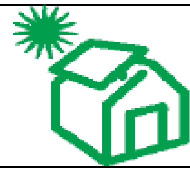
1	Davies, P. J., Emmitt, S., & Firth, S. K. (2013). On-site energy management challenges and opportunities: a contractor's perspective. *Building Research & Information*, *41*(4), 450–468.
2	Ko, J. (2010). *Carbon: Reducing the footprint of the construction process* (No. 6) (pp. 1–65). Strategic Forum for Construction and the Carbon Trust.
3	Mendler, S. F., & Odell, W. (2000). *The HOK Guidebook to Sustainable Design*. New York: John Wiley & Sons, Inc.
4	Rubenstone, J. (2010, September). New Construction Trailer Models Coming to Jobsites in Several Shades of "Green." *ENR.com: Engineering News-Record*. Retrieved February 16, 2014, from http://enr.construction.com/products/product_snapshot/2010/0915-NewConstructionTrailer.asp

A. CPSA NO.: 32

1. CPSA TITLE: Energy-autonomous Pre-manufactured Reusable Facilities	4. DATE: 4/13/2014
2. PRIMARY CONSTRUCTION FUNCTION: Site Facilities & Operations	
3. SECONDARY CONSTRUCTION FUNCTION: Field Engineering	

B. CPSA DESCRIPTION:

For temporary jobsite facilities, consider utilizing pre-fabricated mobile, reusable trailers that are energy-autonomous (or nearly so) and energy-efficient. These may be used in lieu of field-fabricated facilities for such applications as storage trailers, office trailers, guard houses, toilet trailers, and modular tool sheds. Features may include solar and/or PV systems for climate control and/or power supply.



C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Energy consumption	Greenhouse gases	Waste generation	☐	☐	☐	☒	☐
2. SOCIAL	Negligible	-	-	☐	☐	☒	☐	☐
3. ECONOMIC	Project fiscal impacts	-	-	☐	☐	☐	☒	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project safety performance: ☐	3. Project cost performance: ☒	5. None: ☐
2. Project quality performance: ☐	4. Project schedule performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☒	3. Challenging: ☐

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	Local solar conditions are conducive to operation of facility solar-support systems
2	Investment into reusable modular autonomous facility units may be spread over several projects
3	Such units are locally available for rental/leasing

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Cost savings
2	Facility user satisfaction level

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Maintenance support will be needed to ensure that energy systems remain operational
2	Project has limited access to suppliers of such units

I. REFERENCES

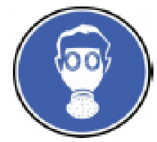
1	Ko, J. (2010). *Carbon: Reducing the footprint of the construction process* (No. 6) (pp. 1–65). Strategic Forum for Construction and the Carbon Trust.
2	Rubenstone, J. (2010, September). New Construction Trailer Models Coming to Jobsites in Several Shades of "Green." *ENR.com: Engineering News-Record*. Retrieved February 16, 2014, from http://enr.construction.com/products/product_snapshot/2010/0915-NewConstructionTrailer.asp
3	Triumph. (2010). NextGen Green Mobile Office. *Triumph - Mobile Offices*. Retrieved February 16, 2014, from http://www.triumphmodular.com/office-nextgen-green-mobile.php
4	Williams Scotsman. (2013). reFit, reConfigure, reThink. *Williams Scotsman - Green Modular Solutions*. Retrieved February 16, 2014, from http://www.willscot.com/mo/solutions-green_offices.php

A. CPSA NO.: 33

1. CPSA TITLE: <u>Indoor Air Quality Improvements</u>	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: Site Facilities & Operations	
3. SECONDARY CONSTRUCTION FUNCTION: None	

B. CPSA DESCRIPTION:

Enhance the indoor air quality of both permanent (i.e., under construction) and temporary facilities by avoiding contamination of HVAC systems, controlling pollutant sources, and interrupting contamination pathways, all, during construction. Sequence the installation of materials to avoid contamination of absorptive materials such as insulation, carpeting, ceiling tile, and gypsum wallboard. Protect stored or installed absorptive materials from moisture damage. Avoid using permanently installed air handlers for temporary heating/cooling during construction. Perform a building flush-out or test the air contaminant levels in the building prior to occupancy. Lastly, consider replacing all filtration media immediately prior to occupancy.



C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	–	N	+	++
1. ENVIRONMENTAL	Indoor air quality	Criteria air pollutants	Odors	☐	☐	☐	☒	☐
2. SOCIAL	Health & safety	Community relationships	-	☐	☐	☐	☒	☐
3. ECONOMIC	Negligible	-	-	☐	☐	☒	☐	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project safety performance: ☒	3. Project cost performance: ☐	5. None: ☐
2. Project quality performance: ☐	4. Project schedule performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☒	3. Challenging: ☐

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	Project involves buildings with human occupants
2	Building HVAC systems are installed and operational early in construction
3	Project management has taken a lead role in endorsing sustainable solutions

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	HVAC testing performance
2	Indoor air quality test results

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Project team members are unaware of threats to air quality (such as volatile organic compounds)
2	Lack of information on immediate activities affecting future activities (such as preservation during construction)

I. REFERENCES

1	Kibert, C. J. (2008). Chapter 11 - Construction Operations. In *Sustainable Construction: Green Building Design and Delivery* (Second Edition., pp. 309–316). New Jersey: John Wiley & Sons, Inc.
2	Light, E. (2007). *IAQ Guidelines for Occupied Buildings Under Construction* (Second Edition.). Chantilly, VA: Sheet Metal and Air Conditioning Contractors' National Association, Inc.
3	U.S. EPA. (2012, April). IAQ Design Tools for Schools - Construction. *U.S. Environmental Protection Agency*. Retrieved September 14, 2013, from http://www.epa.gov/iaq/schooldesign/construction.html
4	USGBC. (2010). *LEED 2009 for New Construction and Major Renovations* (pp. 1–85). U.S. Green Building Council, Inc.

A. CPSA NO.: 34

1. CPSA TITLE: <u>Collection, Remediation, and Reuse of Gray Water and Storm Water</u>	4. DATE: 4/13/2014
2. PRIMARY CONSTRUCTION FUNCTION: <u>Site Facilities & Operations</u>	
3. SECONDARY CONSTRUCTION FUNCTION: <u>Field Engineering</u>	

B. CPSA DESCRIPTION:

Consider the storage and treatment of gray water and/or harvested storm water for non-potable needs, such as sewage conveyance, vehicle washing, urinal and toilet flushing, custodial uses, landscaping, and dust control.

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Water consumption	Waste generation	-	☐	☐	☐	☒	☐
2. SOCIAL	Community infrastructure	-	-	☐	☐	☒	☐	☐
3. ECONOMIC	Project fiscal impacts	-	-	☐	☒	☐	☐	☐

D. THIS CPSA HAS A <u>SIGNIFICANT POSITIVE</u> INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project **<u>safety</u>** performance: ☐	3. Project **<u>cost</u>** performance: ☐	5. None: ☒
2. Project **<u>quality</u>** performance: ☐	4. Project **<u>schedule</u>** performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☒	3. Challenging: ☐

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	Project is located in an area where water is scarce
2	Project construction processes can generate a significant amount of gray water
3	Local regulatory restrictions enable the use of gray water

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Quantity of gray water reused
2	Reduction in consumption of potable water

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	First-cost of water retention system set-up can be excessive
2	Regulatory guidelines may not allow use of gray water

I. REFERENCES

1	ACRP. (2012). *ACRP Report 80 - Guidebook for Incorporating Sustainability into Traditional Airport Projects* (pp. 1–103). Washington D.C.: Airport Cooperative Research Program.
2	Mendler, S. F., & Odell, W. (2000). *The HOK Guidebook to Sustainable Design*. New York: John Wiley & Sons, Inc.
3	Peters, E., Clermont, S., Culberson, S. D., Unzelman, R., Venzon, C. L., Kloiber, A., ... Eastmon, A. (2011a). *ACRP Report 42 - Sustainable Airport Construction Practices* (pp. 1–221). Washington D.C.: Airport Cooperative Research Program.
4	Waylen, C., Thornback, J., & Garrett, J. (2011). *Water: An action plan for reducing water usage on construction sites* (No. 9) (pp. 1–54). Strategic Forum for Construction.

A. CPSA NO.: 35

1. CPSA TITLE: Environmentally-friendly Dust and Erosion Control	4. DATE: 4/13/2014
2. PRIMARY CONSTRUCTION FUNCTION: Site Facilities & Operations	
3. SECONDARY CONSTRUCTION FUNCTION: Field Engineering	

B. CPSA DESCRIPTION:

Develop a dust and erosion control plan that incorporates environmentally-friendly methods and technologies. For example, install a temporary screen around the perimeter of the construction site to prevent fugitive dust emissions and use sweepers equipped with vacuums (or a mechanical means of dust/sediment collection/removal) for road cleaning. For dust control, consider the planting of well-adapted vegetation and/or the collection, storage, and use of stormwater (to reduce/avoid potable water use).

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	–	N	+	++
1. ENVIRONMENTAL	Water consumption	-	-	☐	☐	☐	☒	☐
2. SOCIAL	Health & safety	Local resource depletion	Community relationships	☐	☐	☐	☐	☒
3. ECONOMIC	Project fiscal impacts	-	-	☐	☒	☐	☐	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project safety performance: ☒	3. Project cost performance: ☐	5. None: ☐
2. Project quality performance: ☐	4. Project schedule performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☒	3. Challenging: ☐

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	Adjacent project neighbors are very sensitive to project-generated noise, dust, and/or equipment exhaust
2	Many community residents live adjacent to the project site
3	The local community (and especially project neighbors) are not supportive of the project

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Local air quality metrics
2	Number of complaints from community, agency, or camp residents

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Inadequate information on community's concern for dust
2	Limited project resources to reduce dust emissions

I. REFERENCES

1	Kibert, C. J. (2008). Chapter 11 - Construction Operations. In *Sustainable Construction: Green Building Design and Delivery* (Second Edition., pp. 309–316). New Jersey: John Wiley & Sons, Inc.
2	Peters, E., Clermont, S., Culberson, S. D., Unzelman, R., Venzon, C. L., Kloiber, A., ... Eastmon, A. (2011a). *ACRP Report 42 - Sustainable Airport Construction Practices* (pp. 1–221). Washington D.C.: Airport Cooperative Research Program.
3	Venner, M., & Zeimer, L. (2004). *Environmental Stewardship Practices, Procedures, and Policies for Highway Construction and Maintenance* (pp. 1–850). National Cooperative Highway Research Program.
	Waylen, C., Thornback, J., & Garrett, J. (2011). *Water: An action plan for reducing water usage on construction sites* (No. 9) (pp. 1–54). Strategic Forum for Construction.

A. CPSA NO.: 36

1. CPSA TITLE: Construction and Demolition Waste Management	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: Site Facilities & Operations	
3. SECONDARY CONSTRUCTION FUNCTION: Field Engineering	

B. CPSA DESCRIPTION:

Going beyond regulatory requirements, describe waste reduction goals and specify targets for waste and debris diversion. Prepare and formalize a Construction and Demolition Waste Management Plan that describes the actions that will be taken to reduce solid waste generation, identifies specific approaches to be used in recycling/reuse, presents the name and location of the landfill used for material that cannot be recycled, contains a list of material that may be extracted/recycled/salvaged, and estimates the percentage of waste that will be diverted by this plan (establish metrics for measurement).

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Waste generation	Land use	-	☐	☐	☐	☐	☒
2. SOCIAL	Negligible	-	-	☐	☐	☒	☐	☐
3. ECONOMIC	Negligible	-	-	☐	☐	☒	☐	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project safety performance: ☐	3. Project cost performance: ☐	5. None: ☒
2. Project quality performance: ☐	4. Project schedule performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☒	3. Challenging: ☐

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	The project involves a significant amount of demolition
2	Regional landfill dumping fees are relatively high
3	Local recycling infrastructure is in place

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Portion or volume of total waste recycled or diverted from a landfill
2	Reduction in landfill tipping fees

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Ineffectiveness in sorting and/or storing waste materials to be recycled
2	One or more key contracting parties is not motivated to participate in the recycling program

I. REFERENCES

1	3D/International. (2000). *Construction and Demolition Waste Management Pocket Guide* (pp. 1–26). USA: HQ Air Force Center for Environmental Excellence.
2	ACRP. (2012). *ACRP Report 80 - Guidebook for Incorporating Sustainability into Traditional Airport Projects* (pp. 1–103). Washington D.C.: Airport Cooperative Research Program.
3	Napier, T. (2011, January). Construction Waste Management. *Whole Building Design Guide*. Retrieved July 6, 2011, from http://www.wbdg.org/resources/cwmgmt.php
4	U.S. Army Corps of Engineers. (2003). *Guidance for the Reduction of Demolition Waste through Reuse and Recycling* (Public Works Technical Bulletin No. 200-1-23) (pp. 1–160). Department of the Army.

A. CPSA NO.: 37

1. CPSA TITLE: Collection, Sorting, and Recycling of Construction Wastes	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: Site Facilities & Operations	
3. SECONDARY CONSTRUCTION FUNCTION: Field Engineering	

B. CPSA DESCRIPTION:

Consider the active collection and sorting of construction wastes to facilitate re-use or recycling. Targeted materials may include asphalt, concrete, soil, electrical conduit/wires, wood, paper products, plastic, and paints, among others. In addition, consider performing time-phased recycling where specific waste materials can be extracted and separated for recycling during optimal construction stages. For example, the recycling of wood and gypsum wall board can be optimized during the framing and sheet-rocking stages of construction.

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Waste generation	Land use	-	☐	☐	☐	☐	☒
2. SOCIAL	Community infrastructure	Health & safety	Community relationships	☐	☐	☐	☒	☐
3. ECONOMIC	Negligible	-	-	☐	☐	☒	☐	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project safety performance: ☐	3. Project cost performance: ☐	5. None: ☒
2. Project quality performance: ☐	4. Project schedule performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☒	3. Challenging: ☐

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	Local recycling infrastructure is in place
2	The project involves a significant amount of demolition
3	Other projects in the region can benefit from reuse of waste from this project

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Portion or volume of total waste recycled or diverted from a landfill
2	Reduction in landfill tipping fees

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Local area has no recycling infrastructure/community to support recycling activities
2	Added expense of waste management effort and storage facilities

I. REFERENCES

1	3D/International. (2000). *Construction and Demolition Waste Management Pocket Guide* (pp. 1–26). USA: HQ Air Force Center for Environmental Excellence.
2	Howard, A., Gaughan, M., Hattan, S., & Wilkerson, M. (2012). Lean, Green, and Mean: The IPL Project (pp. 359–366). Presented at the 2012 International Conference on Sustainable Design and Construction, Texas: American Society of Civil Engineers.
3	Napier, T. (2011, January). Construction Waste Management. *Whole Building Design Guide*. Retrieved July 6, 2011, from http://www.wbdg.org/resources/cwmgmt.php
4	U.S. Army Corps of Engineers. (2003). *Guidance for the Reduction of Demolition Waste through Reuse and Recycling* (Public Works Technical Bulletin No. 200-1-23) (pp. 1–160). Department of the Army.

A. CPSA NO.: 38

1. CPSA TITLE: <u>Promotion of Local Workforce Preparedness</u>	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: <u>Craft Labor Management</u>	
3. SECONDARY CONSTRUCTION FUNCTION: <u>Project Management</u>	

B. CPSA DESCRIPTION:

Consider how project leadership can help promote local worker ready-for-work preparedness. This effort should address worker skills development, local secondary education assistance, substance abuse/prevention programs, immigrant labor assistance programs, EHS awareness programs, and transport programs, among others. For example, training materials (safety and quality, among others) can be prepared in all appropriate craft languages to maximize positive impacts on performance.

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Negligible	-	-	☐	☐	☒	☐	☐
2. SOCIAL	Health & safety	Skills development	Community relationships	☐	☐	☐	☐	☒
3. ECONOMIC	Project fiscal impacts	-	-	☐	☐	☐	☒	☐

D. THIS CPSA HAS A <u>SIGNIFICANT POSITIVE</u> INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project <u>safety</u> performance: ☒	3. Project <u>cost</u> performance: ☒	5. None: ☐
2. Project <u>quality</u> performance: ☒	4. Project <u>schedule</u> performance: ☒	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☐	3. Challenging: ☒

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	The region has a shortage of skilled craft labor
2	Many capital projects in the area compete for skilled labor
3	Project will draw from a migrant labor pool

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Local workforce turnover rate
2	Number of labor skill certifications awarded annually

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Limited project resources – lack of staff to support programs
2	Insufficient infrastructure – local educational/training facilities not available

I. REFERENCES

1	Herrick, R. (2012, May). *Workforce Preparedness*. Baytown, TX.
2	NCCER. (2011). NCCER - Training & Certifications. *NCCER*. Retrieved February 13, 2014, from http://www.nccer.org/training-and-certifications
3	Peters, E., Clermont, S., Culberson, S. D., Unzelman, R., Venzon, C. L., Kloiber, A., ... Eastmon, A. (2011a). *ACRP Report 42 - Sustainable Airport Construction Practices* (pp. 1–221). Washington D.C.: Airport Cooperative Research Program.
4	Robichaud, L. B., & Anantatmula, V. S. (2011). Greening Project Management Practices for Sustainable Construction. *Journal of Management in Engineering*, *27*, 48–57.

A. CPSA NO.: 39

1. CPSA TITLE: Expatriates versus Local Employment for Global Projects	4. DATE: 4/13/2014
2. PRIMARY CONSTRUCTION FUNCTION: Craft Labor Management	
3. SECONDARY CONSTRUCTION FUNCTION: Project Management	

B. CPSA DESCRIPTION:

Conduct a value-based impact analysis on use of expatriates versus local employment for global projects. Consider all impacts: safety, quality, schedule, cost, and all aspects of sustainability.

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Negligible	-	-	☐	☐	☒	☐	☐
2. SOCIAL	Health & safety	Skills development	Jobs created	☐	☐	☐	☒	☐
3. ECONOMIC	Project fiscal impacts	-	-	☐	☐	☐	☒	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project safety performance: ☒	3. Project cost performance: ☒	5. None: ☐
2. Project quality performance: ☒	4. Project schedule performance: ☒	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☒	3. Challenging: ☐

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	Project stakeholders and local community leaders are clearly defined and accessible
2	The project has high local content requirements for materials and services
3	The tradeoffs associated with the different sources of employment are not obvious

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Change in local employment from project (percent or number)
2	Effort or resources required to reach employment targets (per hired craft worker or PM staff)

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Difficulty in acquiring reliable information on available craft and professional workforce and associated skill levels
2	Related issues are replete with uncertainty and hidden risks

I. REFERENCES

1	Gray, D. (2013, November). Local content challenges vex Brazil's offshore operators. *Offshore - More Regional Report News*. Retrieved February 16, 2014, from http://www.offshore-mag.com/articles/print/volume-73/issue-11/brazil/local-content-challenges-vex-brazil-s-offshore-operators.html
2	IPIECA. (2011). *Local Content Strategy: A guidance document for the oil and gas industry* (pp. 1–32). International Petroleum Industry Environmental and Conservation Association.
3	McNulty, Y., & Inkson, K. (2013). *Managing Expatriates: A Return on Investment Approach*. New York: Business Expert Press.
4	SHRM. (2010, September). International Assignment Management: Expatriate Policy and Procedure. *Society for Human Resource Management*. Retrieved February 16, 2014, from http://www.shrm.org/TemplatesTools/Samples/Policies/Pages/ExpatriateProcedure%28Expanded%29.aspx

A. CPSA NO.: 40

1. CPSA TITLE: Promote Community Harmony within Diverse Project Workforce	4. DATE: 4/13/2014
2. PRIMARY CONSTRUCTION FUNCTION: Craft Labor Management	
3. SECONDARY CONSTRUCTION FUNCTION: Project Management	

B. CPSA DESCRIPTION:

For international projects, promote community harmony among a diverse workforce by recruiting culturally compatible workers and by thoroughly planning and monitoring interactions/interfaces between the different cultural communities.

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	–	N	+	++
1. ENVIRONMENTAL	Negligible	-	-	☐	☐	☒	☐	☐
2. SOCIAL	Health & safety	Community relationships	-	☐	☐	☐	☐	☒
3. ECONOMIC	Negligible	-	-	☐	☐	☒	☐	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project safety performance: ☒	3. Project cost performance: ☐	5. All: ☐
2. Project quality performance: ☐	4. Project schedule performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☐	3. Challenging: ☒

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	The project is large and complex
2	The project will have a culturally diverse workforce
3	The region has a shortage of skilled craft labor

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Local workforce turnover rate
2	Number of complaints from community, agency, or camp residents

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Lack of awareness of or poorly prepared for cultural diversity within the workforce
2	Age-old cultural hostilities among the project's workforce ethnic groups

I. REFERENCES

1	Ayoko, O. B. (2007). Communication openness, conflict events and reactions to conflict in culturally diverse workgroups. *Cross Cultural Management: An International Journal*, *14*(2), 105–124.
2	FECCA. (2011). Harmony in the Workplace - Delivering the Diversity Dividend. *FECCA - Resources*. Retrieved February 16, 2014, from http://www.fecca.org.au/resources/harmony-in-the-workplace-factsheets
3	Jassawalla, A., Truglia, C., & Garvey, J. (2004). Cross-cultural conflict and expatriate manager adjustment: An exploratory study. *Management Decision*, *42*(7), 837–849.
4	Ling, F. Y., Dulaimi, M. F., & Chua, M. (2012). Strategies for managing migrant construction workers from China, India, and the Philippines. *Journal of Professional Issues in Engineering Education & Practice*, *139*(1), 19–26.

A. CPSA NO.: 41

1. CPSA TITLE: Analysis of Local Materials/Services versus Non-local/Global Alliance	4. DATE: 4/13/2014
2. PRIMARY CONSTRUCTION FUNCTION: Materials Management	
3. SECONDARY CONSTRUCTION FUNCTION: Project Management	

B. CPSA DESCRIPTION:

For field-based procurement, consider local/regional materials and suppliers in lieu of importing resources from more distant sources. Analysis of procurement sources/location should consider product price and availability, delivery time, fuel consumption, jobs generated, and local tax revenues, along with other environmental and social impacts. The selected approach will require compatibility with local content goals and could involve challenges to prior global alliance procurement agreements. In addition, the approach should be supported by compatible work packaging of design and procurement documentation, and consider any effects from any local competing/concurrent projects.

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Energy consumption	Greenhouse gases	Criteria air pollutants	☐	☐	☐	☒	☐
2. SOCIAL	Jobs created	Tax revenue produced	Skills development	☐	☐	☐	☐	☒
3. ECONOMIC	Negligible	-	-	☐	☐	☒	☐	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project safety performance: ☐	3. Project cost performance: ☐	5. None: ☐
2. Project quality performance: ☐	4. Project schedule performance: ☒	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☒	3. Challenging: ☐

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	The project region offers competitive sources for goods and services
2	International alliance-type sourcing is the contractor's standard (default) approach
3	The project has high local content requirements for materials and services

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Contribution of project to local tax revenue
2	Change in local employment from project (percent or number)

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Lack of information on local suppliers and what they offer and can deliver
2	Time and resources required to conduct a thorough analysis on procurement sourcing

I. REFERENCES

1	City of New York DDC. (1999). *High Performance Building Guidelines* (pp. 1–144). New York: City of New York Department of Design and Construction.
2	Stain, L., Wilson, A., & Malin, N. (2002). *GreenSpec Directory: Product Directory with Guideline Specifications* (Third edition.). Vermont: Building Green, Inc.
3	USGBC. (2010). *LEED 2009 for New Construction and Major Renovations* (pp. 1–85). U.S. Green Building Council, Inc.
4	Varghese, J., & Webb, D. (2012). Contractor's Role During the Construction Phase. *Sustainable Construction Magazine*, (Winter 2012), 10–12.

A. CPSA NO.: 42

1. CPSA TITLE: Reduction of Packaging Waste	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: Materials Management	
3. SECONDARY CONSTRUCTION FUNCTION: Site Facilities & Operations	

B. CPSA DESCRIPTION:

Consider reducing packaging waste through vendor participation, using bulk packaging techniques, and/or selecting products with minimal or no packing. Identify suppliers who can deliver materials in sturdy containers (wood/plastic pallets, etc.) and packing materials and require them to reclaim/back-haul empty shipping containers for reuse and recycling. Reuse non-returnable containers on the jobsite to the maximum extent possible.

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	–	N	+	++
1. ENVIRONMENTAL	Waste generation	Land use	-	☐	☐	☐	☐	☒
2. SOCIAL	Negligible	-	-	☐	☐	☒	☐	☐
3. ECONOMIC	Negligible	-	-	☐	☐	☒	☐	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project safety performance: ☐	3. Project cost performance: ☐	5. None: ☒
2. Project quality performance: ☐	4. Project schedule performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☐	3. Challenging: ☒

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	Owner and/or contractor have large market share and can influence shipping methods of vendors/suppliers
2	Recycling of materials is already part of the project team's culture
3	Current methods of packaging/packing material result in excess waste

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Portion or volume of total waste recycled or diverted from a landfill
2	Street value of recycled material

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Suppliers/vendors would need to participate in establishment of more waste-efficient shipping solutions
2	Analysis of packaging waste must be conducted first

I. REFERENCES

1	3D/International. (2000). *Construction and Demolition Waste Management Pocket Guide* (pp. 1–26). USA: HQ Air Force Center for Environmental Excellence.
2	City of New York DDC. (1999). *High Performance Building Guidelines* (pp. 1–144). New York: City of New York Department of Design and Construction.
3	Mendler, S. F., & Odell, W. (2000). *The HOK Guidebook to Sustainable Design*. New York: John Wiley & Sons, Inc.
4	Napier, T. (2011, January). Construction Waste Management. *Whole Building Design Guide*. Retrieved July 6, 2011, from http://www.wbdg.org/resources/cwmgmt.php

A. CPSA NO.: 43

1. CPSA TITLE: Material- and Equipment-handling Strategy	4. DATE: 4/13/2014
2. PRIMARY CONSTRUCTION FUNCTION: Materials Management	
3. SECONDARY CONSTRUCTION FUNCTION: Construction Equipment Management	

B. CPSA DESCRIPTION:

Double handling of material and equipment can be a major cause of project waste and energy consumption. Employ an automated construction materials tracking and warehouse management system, in lieu of manually intensive or semi-automated approaches, to reduce environmental and economic impacts associated with multiple handling of material, including crew idle time, and disruptions to short interval planning (from searching efforts, component loss, or replacement of materials). Consider lay-down yard sizing and location, traffic management, different delivery policies, and scheduling to minimize multiple handling of delivered material/equipment. This strategy is particularly important for large complex projects (industrial projects, etc.) where loss of essential components can have a significant impact on construction processes and the project schedule. Additional related management considerations may include temperature-controlled storage, and snow, rain, and solar UV effects on materials stored outside.

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE --	-	N	+	++
1. ENVIRONMENTAL	Energy consumption	Greenhouse gases	Waste generation	☐	☐	☐	☒	☐
2. SOCIAL	Negligible	-	-	☐	☐	☒	☐	☐
3. ECONOMIC	Project fiscal impacts	-	-	☐	☐	☐	☒	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project **safety** performance: ☐	3. Project **cost** performance: ☒	5. None: ☐
2. Project **quality** performance: ☐	4. Project **schedule** performance: ☒	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☐	3. Challenging: ☒

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	The project is large and complex
2	The project is suffering from low field craft productivity
3	The project site is small in size or congested

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Cycle time from material request to material site delivery
2	Equipment environmental performance

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Limited project resources to deal with a very complex issue
2	Limited project resources to equip and train individuals on sophisticated inventory management system

I. REFERENCES

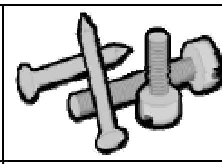
1	Harker, A., Allcorn, W., & Taylor, D. (2007). *Material Logistics Plan: Good Practice Guidance* (pp. 1–58). Banbury, Oxon: Waste & Resources Action Programme.
2	Kibert, C. J. (2008). Chapter 11 - Construction Operations. In *Sustainable Construction: Green Building Design and Delivery* (Second Edition., pp. 309–316). New Jersey: John Wiley & Sons, Inc.
3	Nasir, H., Haas, C. T., Young, D. A., Razavi, S. N., Caldas, C., & Goodrum, P. (2010). An implementation model for automated construction materials tracking and locating. *Canadian Journal of Civil Engineering*, *37*, 588–599.

A. CPSA NO.: 44

1. CPSA TITLE: <u>Sustainable Consumable Materials Management</u>	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: <u>Materials Management</u>	
3. SECONDARY CONSTRUCTION FUNCTION: <u>None</u>	

B. CPSA DESCRIPTION:

Implement reuse and recycling practices to efficiently use and manage consumable materials in a manner that reduces project waste and associated negative sustainability impacts. Consider investigating innovative construction technologies/methods to identify opportunities that improve the utilization of consumables. For example, automatic welding machines can be used, in lieu of manual conventional welding techniques, where possible, to utilize welding rods to the fullest extent. Similar principles can be applied to the use of saw blades, grinding wheels, etc.



C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Waste generation	Land use	-	☐	☐	☐	☒	☐
2. SOCIAL	Negligible	-	-	☐	☐	☒	☐	☐
3. ECONOMIC	Negligible	-	-	☐	☐	☒	☐	☐

D. THIS CPSA HAS A <u>SIGNIFICANT POSITIVE</u> INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project **<u>safety</u>** performance: ☐	3. Project **<u>cost</u>** performance: ☐	5. None: ☒
2. Project **<u>quality</u>** performance: ☐	4. Project **<u>schedule</u>** performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☒	2. Moderate: ☐	3. Challenging: ☐

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	Project involves a significant amount of consumable materials to support construction processes
2	Project waste management efforts have been minimal
3	Project fabrication and/or construction processes involve advanced technologies

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Cost savings
2	Portion or volume of total waste recycled or diverted from a landfill

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Inadequate information to allow proper risk/benefit decision
2	Project-level recycling culture and infrastructure are not in place

I. REFERENCES

1	3D/International. (2000). *Construction and Demolition Waste Management Pocket Guide* (pp. 1–26). USA: HQ Air Force Center for Environmental Excellence.
2	Napier, T. (2011, January). Construction Waste Management. *Whole Building Design Guide*. Retrieved July 6, 2011, from http://www.wbdg.org/resources/cwmgmt.php
3	ToolWatch. (2006). *Construction Resource Management: Improving Contractor Business Performance* (White Paper) (pp. 1–11). ToolWatch. (Public Works Technical Bulletin No. 200-1-23) (pp. 1–160). Department of the Army.
4	U.S. Army Corps of Engineers. (2003). *Guidance for the Reduction of Demolition Waste through Reuse and Recycling* (Public Works Technical Bulletin No. 200-1-23) (pp. 1–160). Department of the Army.

A. CPSA NO.: 45

1. CPSA TITLE: Minimization of Material Surplus	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: Materials Management	
3. SECONDARY CONSTRUCTION FUNCTION: Contracting	

B. CPSA DESCRIPTION:

Employ tight quantity estimation to minimize the generation of material surplus. Ensure that only the correct amount of materials are purchased and delivered to the site. For example, order 80% of the needed materials during the design phase and only order the remaining amount later in the project after quantities are well understood. This strategy is particularly relevant for cost-reimbursable projects.

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Waste generation	Land use	-	☐	☐	☐	☒	☐
2. SOCIAL	Negligible	-	-	☐	☐	☒	☐	☐
3. ECONOMIC	Project fiscal impacts	-	-	☐	☐	☐	☒	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project safety performance: ☐	3. Project cost performance: ☒	5. None: ☐
2. Project quality performance: ☐	4. Project schedule performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☒	3. Challenging: ☐

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	The construction contract is cost-reimbursable type
2	The project team is interested in improving the accuracy of quantity take-off estimates
3	Project owner is not attentive to contractor procurement approaches

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Cost savings
2	Portion or volume of total waste recycled or diverted from a landfill

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Many contractors have difficulty accurately estimating quantities
2	General inattention to the amount of waste generated by a construction project

I. REFERENCES

1	3D/International. (2000). *Construction and Demolition Waste Management Pocket Guide* (pp. 1–26). USA: HQ Air Force Center for Environmental Excellence.
2	Agyekum, K., Ayarkwa, J., & Adjei-Kumi, T. (2013). Minimizing Materials Wastage in Construction - A Lean Construction Approach. *Journal of Engineering and Applied Science*, *5*(1), 125–146.
3	WRAP. (2007a). *Achieving effective Waste Minimisation: Guidance for construction clients, design teams and contractors* (pp. 1–24). Banbury, Oxon: Waste & Resources Action Programme.
4	WRAP. (2007b). *Reducing material wastage in construction* (pp. 1–23). Banbury, Oxon: Waste & Resouces Action Programme.

A. CPSA NO.: 46

1. CPSA TITLE: Management of Surplus Materials	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: Materials Management	
3. SECONDARY CONSTRUCTION FUNCTION: None	

B. CPSA DESCRIPTION:

Consider donating unused construction materials to local organizations that can repurpose them in the community. Surplus material may also be put back into the corporate inventory, sent to other sites, or advertised/resold. For example, overstocked, used, and discontinued/salvaged building materials may be donated to non-profit organizations such as local exchanges or Habitat for Humanity's ReStore.

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Waste generation	Land use	-	☐	☐	☐	☒	☐
2. SOCIAL	Community service/donations	Community relationships	-	☐	☐	☐	☒	☐
3. ECONOMIC	Negligible	-	-	☐	☐	☒	☐	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project **safety** performance: ☐	3. Project **cost** performance: ☐	5. None: ☒
2. Project **quality** performance: ☐	4. Project **schedule** performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☒	2. Moderate: ☐	3. Challenging: ☐

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	The project involves a significant amount of demolition
2	The project team is interested in improving the accuracy of quantity take-off estimates
3	Many material items are purchased in large bulk quantities

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Portion or volume of total waste recycled or diverted from a landfill
2	Street value of recycled material

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Local infrastructure may not exist to accept materials
2	Limited project resources may not provide for storage locations, transportation, or other activities to manage surplus

I. REFERENCES

1	3D/International. (2000). *Construction and Demolition Waste Management Pocket Guide* (pp. 1–26). USA: HQ Air Force Center for Environmental Excellence.
2	Napier, T. (2011, January). Construction Waste Management. *Whole Building Design Guide*. Retrieved July 6, 2011, from http://www.wbdg.org/resources/cwmgmt.php
3	U.S. Army Corps of Engineers. (2003). *Guidance for the Reduction of Demolition Waste through Reuse and Recycling* (Public Works Technical Bulletin No. 200-1-23) (pp. 1–160). Department of the Army.
4	WRAP. (2007a). *Achieving effective Waste Minimisation: Guidance for construction clients, design teams and contractors* (pp. 1–24). Banbury, Oxon: Waste & Resources Action Programme.

A. CPSA NO.: 47

1. CPSA TITLE: Selection and Replacement of Construction Equipment	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: Construction Equipment Management	
3. SECONDARY CONSTRUCTION FUNCTION: None	

B. CPSA DESCRIPTION:

Consider the selection and deployment of fuel-efficient construction equipment for power generators, lighting, and other heavy equipment. Develop and employ an environmentally-conscious heavy construction equipment acquisition and replacement policy to improve the emissions performance of the heavy construction equipment fleet. This strategy should also consider the re-use and recycling of heavy construction equipment, and promote the progressive retirement of diesel-powered machines in favor of those fueled by cleaner energy sources such as liquefied natural gas (LNG).

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Energy consumption	Greenhouse gases	Noise	☐	☐	☐	☐	☒
2. SOCIAL	Negligible	-	-	☐	☐	☒	☐	☐
3. ECONOMIC	Project fiscal impacts	-	-	☐	☒	☐	☐	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project safety performance: ☐	3. Project cost performance: ☐	5. None: ☒
2. Project quality performance: ☐	4. Project schedule performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☐	3. Challenging: ☒

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	Project involves a substantial amount of heavy construction equipment
2	Contractor's existing equipment fleet includes many old pieces that are not fuel-efficient
3	The project is located in an area with recognized air quality problems

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Fuel consumption efficiency
2	Equipment environmental performance

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Limited project resources (e.g., funding) to allow for purchase or lease of "greener" equipment, if more expensive
2	Insufficient availability of needed industry resources that support equipment operations (e.g., fueling) or maintenance, required by new, more sustainable equipment options.

I. REFERENCES

1	Ninmann, T. (2012). Caterpillar Unveils First Hybrid Excavator: This "Next Generation" Hybrid delivers industry-leading productivity with up to 50% greater fuel efficiency. *Sustainable Construction Magazine*, (Winter 2012), 19–24.
2	Scanlon, B. (2013). The Power of Propane: Contractors complement eco-friendly building with alternative equipment on the jobsite. *Sustainable Construction Magazine*, (Summer 2013), 10–13.
3	U.S. EPA. (2013, January). National Clean Diesel Campaign (NCDC) - Technologies Overview. *U.S. Environmental Protection Agency*. Retrieved September 18, 2013, from http://www.epa.gov/cleandiesel/technologies/index.htm
4	Venner, M., & Zeimer, L. (2004). *Environmental Stewardship Practices, Procedures, and Policies for Highway Construction and Maintenance* (pp. 1–850). National Cooperative Highway Research Program.

A. CPSA NO.: 48

1. CPSA TITLE: Right-sizing of Construction Equipment	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: Construction Equipment Management	
3. SECONDARY CONSTRUCTION FUNCTION: Field Engineering	

B. CPSA DESCRIPTION:

Consider the right-sizing of construction equipment, recognizing cost, availability, convenience, capacity, and sustainability aspects, such as fuel type, quantity and type of emissions, noise, and other performance issues. Consider leasing or renting of any equipment not currently owned.

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	–	N	+	++
1. ENVIRONMENTAL	Energy consumption	Greenhouse gases	Noise	☐	☐	☐	☒	☐
2. SOCIAL	Negligible	-	-	☐	☐	☒	☐	☐
3. ECONOMIC	Project fiscal impacts	-	-	☐	☐	☐	☒	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project safety performance: ☐	3. Project cost performance: ☒	5. None: ☐
2. Project quality performance: ☐	4. Project schedule performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☒	3. Challenging: ☐

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	Construction equipment capacity is often much higher than needed for the task
2	Construction equipment selection decisions are most often driven by convenient availability
3	Construction equipment fleet managers and operators are mostly unaware of environmental effects of equipment operations

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Fuel consumption efficiency
2	Change in equipment rental expense

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Lack of infrastructure – availability of equipment
2	Inadequate information to make right-sizing decisions for construction equipment acquisitions

I. REFERENCES

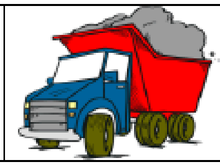
1	EA. (2014, January). Sustainable Construction. *Environment Agency*. Retrieved February 16, 2014, from http://www.environment-agency.gov.uk/business/sectors/136252.aspx
2	Ko, J. (2010). *Carbon: Reducing the footprint of the construction process* (No. 6) (pp. 1–65). Strategic Forum for Construction and the Carbon Trust.
3	Peters, E., Clermont, S., Culberson, S. D., Unzelman, R., Venzon, C. L., Kloiber, A., ... Eastmon, A. (2011a). *ACRP Report 42 - Sustainable Airport Construction Practices* (pp. 1–221). Washington D.C.: Airport Cooperative Research Program.
4	Venner, M., & Zeimer, L. (2004). *Environmental Stewardship Practices, Procedures, and Policies for Highway Construction and Maintenance* (pp. 1–850). National Cooperative Highway Research Program.

A. CPSA NO.: 49

1. CPSA TITLE: Use of Full Transport/Equipment Capacity	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: Construction Equipment Management	
3. SECONDARY CONSTRUCTION FUNCTION: None	

B. CPSA DESCRIPTION:

Manage equipment usage and transport in such a manner so to avoid inefficient usage, excessive emissions, and other undesired impacts (e.g. noise). For example, have lorries fully-loaded before hauling non-schedule-critical deliveries, and use generators of appropriate capacity to avoid waste.



C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Energy consumption	Greenhouse gases	Noise	☐	☐	☐	☒	☐
2. SOCIAL	Traffic	-	-	☐	☐	☐	☒	☐
3. ECONOMIC	Project fiscal impacts	-	-	☐	☐	☐	☒	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project safety performance: ☐	3. Project cost performance: ☒	5. None: ☐
2. Project quality performance: ☐	4. Project schedule performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☐	3. Challenging: ☒

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	Project involves many small, uncoordinated deliveries
2	Transport equipment tends to be oversized relative to needs
3	The project is located in an area with significant traffic congestion

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Proportion of truck deliveries that are at or near full capacity
2	Equipment capacity utilization

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Supplier and/or carrier buy-in to project-level logistics plans
2	Coordination of transport trips is a knowledge- and effort-intensive pursuit

I. REFERENCES

1	Ko, J. (2010). *Carbon: Reducing the footprint of the construction process* (No. 6) (pp. 1–65). Strategic Forum for Construction and the Carbon Trust.
2	U.S. EPA. (2013, January). National Clean Diesel Campaign (NCDC) - Technologies Overview. *U.S. Environmental Protection Agency*. Retrieved September 18, 2013, from http://www.epa.gov/cleandiesel/technologies/index.htm
3	Yates, J. K. (2008). *Sustainable Industrial Construction* (Research Report No. 250-11) (pp. 1–169). Construction Industry Institute.

A. CPSA NO.: 50

1. CPSA TITLE: Reduction in Idling of Construction Equipment	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: Construction Equipment Management	
3. SECONDARY CONSTRUCTION FUNCTION: None	

B. CPSA DESCRIPTION:

Consider the environmental and social impacts from equipment idling. Consider establishing a time limit for vehicle idling, implementing idle control technologies (e.g., after market auxiliary heaters), determining methods to reduce wait times for material unloading, and improving coordination between the constructor and supplier to avoid delivery queues. Evaluate the benefits of delivering material early in the day to avoid trucking on high ozone/congestion days. The procurement department should consider how to balance local deliveries versus long haul services using tools such as GPS and work with local vendors to fill slow mornings.

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Energy consumption	Greenhouse gases	Noise	☐	☐	☐	☒	☐
2. SOCIAL	Negligible	-	-	☐	☐	☒	☐	☐
3. ECONOMIC	Negligible	-	-	☐	☐	☒	☐	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project safety performance: ☐	3. Project cost performance: ☐	5. None: ☒
2. Project quality performance: ☐	4. Project schedule performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☒	3. Challenging: ☐

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	Projects in non-arctic or non-desert environments
2	The project schedule and budget are flexible
3	The project has a complex logistics program

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Cycle time from material request to material site delivery
2	Amount of vehicle idling

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Project is in arctic/extreme environment that requires equipment to run at all times in order to remain operational
2	Project is schedule driven and deliveries must occur at all times

I. REFERENCES

1	Ko, J. (2010). *Carbon: Reducing the footprint of the construction process* (No. 6) (pp. 1–65). Strategic Forum for Construction and the Carbon Trust.
2	U.S. DE. (2013). Alternative Fuels Data Center. *U.S. Department of Energy - Energy Efficiency & Renewable Energy*. Retrieved September 14, 2013, from http://www.afdc.energy.gov/
3	U.S. EPA. (2013, January). National Clean Diesel Campaign (NCDC) - Technologies Overview. *U.S. Environmental Protection Agency*. Retrieved September 18, 2013, from http://www.epa.gov/cleandiesel/technologies/index.htm
4	Venner, M., & Zeimer, L. (2004). *Environmental Stewardship Practices, Procedures, and Policies for Highway Construction and Maintenance* (pp. 1–850). National Cooperative Highway Research Program.

A. CPSA NO.: 51

1. CPSA TITLE: Inspection and Maintenance of Construction Equipment	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: Construction Equipment Management	
3. SECONDARY CONSTRUCTION FUNCTION: None	

B. CPSA DESCRIPTION:

Develop and apply a systematic construction equipment inspection and maintenance program to reduce environmental impacts associated with inefficient equipment performance, equipment breakdowns, and the spill of hazardous fluids (oil, fuel, hydraulic, cooling, transmission, etc.). Consider establishing a dedicated centralized area, in lieu of satellite locations, that is capable of providing regular equipment inspection, maintenance, and repair services and can handle/contain fluid spills.

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Energy consumption	Greenhouse gases	Water quality	☐	☐	☐	☒	☐
2. SOCIAL	Negligible	-	-	☐	☐	☒	☐	☐
3. ECONOMIC	Negligible	-	-	☐	☐	☒	☐	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project **safety** performance: ☐	3. Project **cost** performance: ☐	5. None: ☒
2. Project **quality** performance: ☐	4. Project **schedule** performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☒	3. Challenging: ☐

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	The project site is small in size or congested
2	Contractors and subcontractors have equipment maintenance programs in place
3	Project involves a substantial amount of heavy construction equipment

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Equipment environmental performance
2	Equipment inspection frequency

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Project is spread over a large geographic area
2	Equipment is maintained by several different contractors

I. REFERENCES

1	Peters, E., Clermont, S., Culberson, S. D., Unzelman, R., Venzon, C. L., Kloiber, A., ... Eastmon, A. (2011a). *ACRP Report 42 - Sustainable Airport Construction Practices* (pp. 1–221). Washington D.C.: Airport Cooperative Research Program.
2	Strombom, C. (2007, December). Highway Sustainability Checklist Version 6. Parsons Brinckerhoff. Retrieved from http://www.environment.transportation.org/environmental_issues/sustainability/recent_dev_archive.aspx?year=2008#bookmarkPBsHighwaySustainabilityChecklistReceivesAward
3	Venner, M., & Zeimer, L. (2004). *Environmental Stewardship Practices, Procedures, and Policies for Highway Construction and Maintenance* (pp. 1–850). National Cooperative Highway Research Program.

A. CPSA NO.: 52

1. CPSA TITLE: Tire-cleaning of Roadworthy Vehicles	4. DATE: 4/13/2014
2. PRIMARY CONSTRUCTION FUNCTION: Construction Equipment Management	
3. SECONDARY CONSTRUCTION FUNCTION: Site Facilities & Operations	

B. CPSA DESCRIPTION:

Study different approaches to tire-cleaning of roadworthy construction trucks. Consider the use of truck tire washing stations (i.e. a designated wash area with a means of collecting and properly disposing of liquid wastes) and placement of rumble strips/compost layer at egress points to minimize tracking material offsite onto public roads and potentially into storm drains. If effective, consider using site pavement gravel/rip-rap and/or non-potable water as ways of cleaning truck tires in lieu of using potable water. Be sure to regularly inspect egress points and adjacent offsite roads and clean them as necessary (especially before predicted rain events).

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Water consumption	-	-	☐	☐	☐	☒	☐
2. SOCIAL	Health & safety	Community infrastructure	Community relationships	☐	☐	☐	☒	☐
3. ECONOMIC	Project fiscal impacts	-	-	☐	☒	☐	☐	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project safety performance: ☐	3. Project cost performance: ☐	5. None: ☒
2. Project quality performance: ☐	4. Project schedule performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☒	2. Moderate: ☐	3. Challenging: ☐

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	Project execution involves large-scale earthwork and grading operations
2	Local jurisdiction requires clean-up of any materials placed on roadway
3	The project is located in an area with significant traffic congestion

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Quantity of grey water reused
2	Number of complaints from community, agency, or camp residents

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Effort will involve both front-end cost and operations cost
2	Policy compliance by independent truckers may be problematic

I. REFERENCES

1	Peters, E., Clermont, S., Culberson, S. D., Unzelman, R., Venzon, C. L., Kloiber, A., ... Eastmon, A. (2011a). *ACRP Report 42 - Sustainable Airport Construction Practices* (pp. 1–221). Washington D.C.: Airport Cooperative Research Program.
2	Strombom, C. (2007, December). Highway Sustainability Checklist Version 6. Parsons Brinckerhoff. Retrieved from http://www.environment.transportation.org/environmental_issues/sustainability/recent_dev_archive.aspx?year=2008#bookmarkPBsHighwaySustainabilityChecklistReceivesAward
3	Venner, M., & Zeimer, L. (2004). *Environmental Stewardship Practices, Procedures, and Policies for Highway Construction and Maintenance* (pp. 1–850). National Cooperative Highway Research Program.
4	Waylen, C., Thornback, J., & Garrett, J. (2011). *Water: An action plan for reducing water usage on construction sites* (No. 9) (pp. 1–54). Strategic Forum for Construction.

A. CPSA NO.: 53

1. CPSA TITLE: Quality Management and Facility Start-up Planning	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: Quality Management, Commissioning, & Handover	
3. SECONDARY CONSTRUCTION FUNCTION: None	

B. CPSA DESCRIPTION:

Plan field construction quality management, pre-commissioning, commissioning, initial operations, and other startup-related activities in a manner that optimizes safety performance, environmental performance, and energy consumption during these stages. As part of these planning efforts, seek to optimize resource utilization and, if applicable, minimize the amount of rejected product resulting from initial manufacturing operations.

C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	–	N	+	++
1. ENVIRONMENTAL	Energy consumption	Greenhouse gases	Waste generation	☐	☐	☐	☒	☐
2. SOCIAL	Health & safety	-	-	☐	☐	☐	☒	☐
3. ECONOMIC	Project fiscal impacts	-	-	☐	☐	☐	☒	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project safety performance: ☒	3. Project cost performance: ☒	5. None: ☐
2. Project quality performance: ☒	4. Project schedule performance: ☒	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☐	3. Challenging: ☒

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	The owner and general contractor are interested in optimizing facility commissioning to improve the overall quality and performance of the final product
2	Commissioning team is familiar with sustainability concepts
3	Manufactured goods that are rejected product can have alternative uses

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Contract requirement that sustainability be included in the project execution plan
2	Commissioning resource efficiency

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Inadequate information available before Commissioning team becomes involved
2	Inadequate information on how to recognize and optimize sustainability parameters

I. REFERENCES

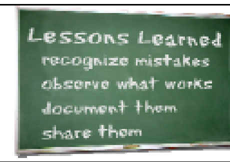
1	ACRP. (2012). *ACRP Report 80 - Guidebook for Incorporating Sustainability into Traditional Airport Projects* (pp. 1–103). Washington D.C.: Airport Cooperative Research Program.Washington D.C.
2	Kibert, C. J. (2008). Chapter 11 - Construction Operations. In *Sustainable Construction: Green Building Design and Delivery* (Second Edition., pp. 309–316). New Jersey: John Wiley & Sons, Inc.
3	USGBC. (2010). *LEED 2009 for New Construction and Major Renovations* (pp. 1–85). U.S. Green Building Council, Inc.
4	Varghese, J. (2013). Contractor's Role During Construction Closeout. *Sustainable Construction Magazine*, (Spring 2013), 10–13.

A. CPSA NO.: 54

1. CPSA TITLE: Sustainability Lessons Learned	4. DATE: 2/17/2014
2. PRIMARY CONSTRUCTION FUNCTION: Quality Management, Commissioning, & Handover	
3. SECONDARY CONSTRUCTION FUNCTION: None	

B. CPSA DESCRIPTION:

Review sustainability performance as part of the post-implementation evaluation report. Consider holding a meeting with key stakeholders to identify sustainability successes, evaluate opportunities for improvements, and collect lessons learned for enhancing the sustainability of future projects. Consider this activity an opportunity for benchmarking the project's sustainability performance.



C. SUSTAINABILITY IMPACTS CHARACTERIZATION:

PRIMARY IMPACTS	MOST AFFECTED AREAS/RESOURCES			IMPACT MAGNITUDE				
				--	-	N	+	++
1. ENVIRONMENTAL	Energy consumption	Waste generation	Water consumption	☐	☐	☐	☒	☐
2. SOCIAL	Health & safety	Community infrastructure	-	☐	☐	☐	☒	☐
3. ECONOMIC	Negligible	-	-	☐	☐	☒	☐	☐

D. THIS CPSA HAS A SIGNIFICANT POSITIVE INFLUENCE ON THE FOLLOWING CONVENTIONAL PROJECT PERFORMANCE CRITERIA:

1. Project **safety** performance: ☐	3. Project **cost** performance: ☐	5. None: ☒
2. Project **quality** performance: ☐	4. Project **schedule** performance: ☐	

E. EASE OF ACCOMPLISHMENT/IMPLEMENTATION:

1. Easy: ☐	2. Moderate: ☒	3. Challenging: ☐

F. PROJECT CONDITIONS THAT LEVERAGE BENEFITS FROM THE CPSA:

1	Project management has take a lead roles in endorsing sustainable solutions
2	Significant sustainability activities occurred on the project
3	The project is located in an environmentally/socially-sensitive area

G. POTENTIAL SUSTAINABILITY PERFORMANCE OUTPUT METRICS:

1	Percent of projects with Sustainability Performance section in project reports
2	Percent of projects that document sustainability lessons-learned

H. BARRIERS TO SUCCESSFUL CPSA IMPLEMENTATION:

1	Significant numbers of individuals involved with sustainability leave the project prior to the opportunity to conduct the review or meeting
2	Lessons Learned system not in place; therefore difficult to disseminate findings and incorporate into future projects

I. REFERENCES

1	ACRP. (2012). *ACRP Report 80 - Guidebook for Incorporating Sustainability into Traditional Airport Projects* (pp. 1–103). Washington D.C.: Airport Cooperative Research Program.
2	Peters, E., Clermont, S., Culberson, S. D., Unzelman, R., Venzon, C. L., Kloiber, A., ... Eastmon, A. (2011a). *ACRP Report 42 - Sustainable Airport Construction Practices* (pp. 1–221). Washington D.C.: Airport Cooperative Research Program.
3	Varghese, J. (2013). Contractor's Role During Construction Closeout. *Sustainable Construction Magazine*, (Spring 2013), 10–13.
4	Varghese, J., & Webb, D. (2012). Contractor's Role During the Construction Phase. *Sustainable Construction Magazine*, (Winter 2012), 10–12.

Appendix D - Construction Sustainability Process

Project construction teams are advised to integrate construction sustainability and CPSA implementation with existing conventional construction planning and execution processes. Such integration will help ensure alignment of related work processes with overall project goals and objectives. Guidance for such integration is provided in this section.

Figure D.1 below presents an overview of the recommended process for incorporating or integrating sustainability within the context of capital projects during construction. The process includes seven distinct steps, all of which are important regardless of construction contracting approach or division of responsibilities between owner and contractor. With respect to optimal process timing, the sooner this process is initiated, the better. Table D.1 below provides additional information on the process steps and associated implementation resources.

Figure D.1: Process for Sustainability during Construction

Table D.1: Steps in Implementation Process

#	Step	Description	Resources
1	**Establish Objectives**	Establish construction phase sustainability objectives and relative priorities and include these in the Project Execution Plan. If needed, train and align the team on RT 304 process and tools. Consult learnings from prior implementations.	Implementation Resource (CPSA Catalog)
2	**Rank Top Actions**	Apply the CPSA Screening Tool and identify top-ranked CPSAs for further consideration (in Step 3).	CPSA Screening Tool
3	**Select Actions**	Conduct team discussions on possible CPSA implementation and expected impacts. Review barriers, related metrics, implementation requirements, past experience, etc. Formalize selection of CPSAs for implementation.	Implementation Resource (CPSA Catalog)
4	**Plan Action Implementation**	Plan detailed CPSA implementation and incorporate details into the Project Execution Plan, including roles/responsibilities, resources, schedule milestones, and beneficial metrics. Establish the current baseline and set a project target for the CPSA Implementation Index.	CPSA Implementation Index
5	**Implement Actions**	Implement all the selected individual CPSAs.	--
6	**Measure Outcomes**	Monitor implementation performance, take course corrections, and measure interim input metrics at appropriate intervals. Recognize successes and their sources. Upon project completion, measure final implementation input and output metrics (as desired) and analyze results.	CPSA Implementation Index
7	**Improve Process**	Post-implementation: Identify and document implementation lessons learned. Update or enhance support processes and tools.	--

Appendix E. In-Depth Methods for Examining Sustainability Issues

1. Economic Input-Output/Environmental Life Cycle Assessment (EIO-LCA)

LCA estimates the "cradle-to-grave" environmental impacts of a product, process, service, or policy that extend beyond its immediate scope. For example, while the combustion of bio-fuels emits fewer greenhouse gases than conventional gasoline, the production of liquid bio-fuels induces a whole host of activities throughout the supply chain of agricultural products, and some research indicates that these supply-chain activities can erode some of the benefits derived during fuel combustion itself. Current LCA models have some limitations in that not all supply-chain environmental effects are incorporated into the analysis (such as solid waste impacts, among others). In addition, social and economic sustainability impacts are also excluded from an LCA analysis.

2. Benefit-Cost Analysis (BCA)

BCA is a systematic method for estimating and comparing the costs and benefits of decisions, projects, or policies. In BCA, all non-monetary outcomes are converted to monetary terms, which can involve literature reviews, independent analyses, expert judgment, estimation, or some combination thereof. The steps involved in completing a BCA include (1) defining a planning horizon, study scope, and discount rate (2) characterizing and estimating all expected benefits and costs (3) monetization of all outcomes (4) an engineering economic analysis to account for benefits and costs that occur at different times throughout the planning horizon and (5) interpretation of results and modeling of uncertainty and variation. BCA can also help clarify the role of different stakeholders such as public and private sector participants that may be involved in the decision. For example, the decision to remove NO_x and SO_x from power plant emissions increases the private cost of providing electricity, but results in public health and environment benefits in excess of the investment.

3. **Cost-Effectiveness (CE) Analysis**

CE is similar to BCA except one or more outcomes are not converted to monetary flows. For example, since there is no clear U.S. market for greenhouse gases, options for reducing greenhouse gases are often compared using CE analysis. Consider the decision to either purchase more efficient generators versus solar photovoltaic panels for the purpose of reducing greenhouse gases. Each decision has different costs, benefits, and expected reductions in greenhouse gases. For each alternative over the specified planning horizon, the CE is computed as total greenhouse gases reduced divided by the sum of the monetary costs and benefits (measured in units of *greenhouse gases reduced / dollar).* However, analysts should track not only the CE of decision alternatives, but also the net benefits and net costs. For example, the decision to replace all temporary lighting with solid state lighting might be very cost effective, but there may not be many temporary light fixtures to replace (therefore few net benefits). Similarly, the decision to install solar photovoltaic panels on trailers may be very cost effective, but the high initial cost may be problematic.

4. **Descriptive Case Study**

A descriptive case study is a narrative description of an actual implementation of a CPSA. The case study documentation should provide descriptive details on project context, owner/contractor organizations and key personnel, CPSA planning steps, CPSA implementation successes and challenges, and resulting performance metrics and achievement levels, among other parameters. Comparative analysis of multiple case studies (differentiated by various project contexts, for example) generally offers additional learnings into CPSA implementation.

5. **Data Collection/Analysis**

In the context of CPSAs, can we learn something about the broader industry or sub-sector (i.e. population) by analyzing the characteristics of a smaller data set (i.e. sample)? Significant CPSAs supported by little previous research may benefit from a related data collection and analysis effort. Such a study may focus on the effectiveness of the CPSA under different conditions or relative to one or more alternative approaches. Critical to the success of this study methodology is the feasibility of data collection (particularly from source access and adequacy of data collection duration perspectives) and the adequacy of ultimate data sample size. The larger the number of study variables (or "data bins") examined concurrently, the greater the data sample size required for a successful analysis. Results of such studies may be descriptive and/or inferential in nature. Descriptive statistics seek to characterize data samples and sub-samples with the intent of learning more about the broader population. Inferential statistics, such as conventional regression analysis, seek to formally challenge a stated hypothesis or to better understand dependency or causal linkages between dependent and independent variables. Subsequent tests of statistical significance provide a measure of the reliability of statistical conclusions, particularly as they relate to sample size and/or robustness.

6. Decision Analysis/ Simulation

A Decision Analysis should focus on a challenging or difficult CPSA decision and provide details on decision context, decision alternatives, decision makers and their risk preferences, decision selection criteria and objective function, criteria sub-components and weightings, decision drivers and determinants (depicted graphically on an influence diagram), data attributes (that characterize data sources and associated reliability), sensitivity analyses, computation of the value of perfect information, decision trees and/or Monte Carlo simulation analysis, objective function computations, and decision conclusion & recommendation, among other features.

7. Work Process Formalization

Work Process (WP) Formalization recognizes and fully describes a recommended best-practice for industry implementation. WP description typically includes details on corporate and project contexts, participating organizational entities, sequential work process steps, recommended resource input and performance output metrics, among other descriptive features. Field validation of a work process is needed to establish or assert "best-practice" status. Such validation may involve one or more Descriptive Case Studies (see #4 above), field data collection/analysis (see # 5 above), review/assessment by a secondary expert panel, or some other approach to validation.

8. Field Demonstration

A Field Demonstration is one way to exhibit and/or test a new, innovative CPSA in the context of a real project. This analysis method often incorporates elements of both method #4 Descriptive Case Study and/or method #7 Work Process Formalization. CPSA implementation should be assessed for successes, challenges, implementation lessons-learned, and recommendations for enhancement of the CPSA itself. A successful field demonstration will require an appropriate implementation test-bed and supportive partner/implementation host.

9. Implementation Tools

Many CPSAS will benefit from one or more implementation tools. Such tools may take the form of a checklist, spreadsheet tool, selection tool, work process model, or some other form. Such tools may also serve as a complement to one of the other in-depth methods described above.

Appendix F - CPSA #9 Guidance: Paperless Communication and Construction Documentation

Description of CPSA:

Replace hardcopy-based communications with electronic/digital forms wherever possible. Consider developing and implementing digital data collection systems and real-time field reporting technologies to electronically streamline traditional paper-based processes and further reduce the reliance on paper files and documents during construction. Adopting green meeting practices can further reduce negative sustainability impacts.

Examples of eco-friendly meeting practices include distributing meeting material electronically, arranging meetings via telephone or Internet to reduce travel, and encouraging carpooling or public transportation when travel cannot be avoided. If printing is required, modify the default setting of the printer to print double-sided and encourage recycling of all documents

Overview

Project communications are increasingly exclusively digital, transitioning from conventional paper-based communications. Each of these methods of communication has significantly different environmental implications, both in their supply chain and during use. This detailed case study uses environmental life cycle assessment (LCA) to characterize environmental implications of digital versus paper communications for U.S. construction services. The LCA phases considered include raw materials extraction, manufacturing, transportation, and use (i.e., “cradle-to-gate”). All environmental flows are normalized to $1M of construction services. Study results should help project managers better understand the environmental efficacy of digital correspondences, providing decision support to integrate digital correspondence in a more environmentally neutral manner.

Current Status

Details regarding the CPSA #9 in-depth analysis were not available at the time this thesis was written.

Appendix G. CPSA #28 Checklist: Sustainable Temporary Facilities/Services

Description of CPSA:

Optimize the planning of temporary site facilities. Consider the sustainability impacts related to the scoping, sizing, location, and layout of: staging areas, laydown areas, material storage, fabrication shops, stockpiles, borrow pits, fuel storage, refueling stations, tool storage, parking lots, field offices, dining/ break facilities, toilet facilities, vertical transportation, storm drainage, temporary power generation, site lighting, and infrastructure tie-ins, etc. Consider both mobile/temporary and semi-permanent options. Consider related impacts from any separate, remote locations. Also evaluate the related special challenges and opportunities associated with projects located in dense urban areas or extremely remote rural areas, such as cell tower communications capacity, among others. Consider the implications of sequencing temporary facilities and construction site aesthetics for some projects.

Overview

A checklist for the planning/designing of sustainable temporary site facilities/services has been developed and is intended to assist project teams in their assessments of how temporary facilities at construction jobsites may be made more sustainable. The checklist addresses the following nine temporary site facility/service issues: temporary site lighting, temporary water sourcing and distribution, site dewatering systems, temporary buildings, jobsite usage and layout, site waste management, soil and gravel borrow pits, worker transport, and worker camp. The checklist tool have been provided starting on the next page.

CPSA #28. Sustainable Temporary Site Facilities/Services Checklist Tool

OBJECTIVE: This tool is intended to assist project teams in their assessments of how temporary facilities at construction jobsites may be made more sustainable.

			Sustainability Impact Potential												
			Environmental							Social					
Considered ? √	Item #	Temporary Site Facility or Service	Energy Consum'n	Air Quality/ GHG	Water Consum'n	Water Quality	Material Consum'n	Solid Waste	Noise or Odors	Health & Safety	Comm. Economy	Skills Development	Traffic	Infrastr. Resources	Sustainability-Related Decisions; Impacts; Links to Other CPSAs
☐	1	Temporary Power Sourcing & Distribution													*See CPSA #30. Source of On-site Power; and CPSA #31. Site Energy Management.*
☐	2	Temporary Site Lighting	+	+						+				+	Related Decisions: Economy is enhanced when temporary site lighting can be provided (entirely or partially) by permanent lighting systems. Effective planning and design of temporary lighting systems can result in energy-efficient system operation, and less light-pollution in the surrounding community. Renewable energy options for power sourcing, if available, should be considered. Impacts: Energy-efficiency (and associated reduction to carbon and air pollution), along with less light pollution can result from effective planning and design of temporary site lighting. Effective site lighting can also enhance worker productivity and site safety.

☐	**3**	**<u>Temporary Water Sourcing & Distribution</u>**			+	+				+			+	+	**<u>Related Decisions</u>:** Economy is enhanced when temporary water needs can be provided (entirely or partially) via permanent water supply systems. Sustainability-sensitive decisions on temporary water sourcing may pertain to use of wells/groundwater, use of trucks to transport water to the site, or use of one or more temporary pipelines. **<u>Impacts</u>:** Impacts from water sourcing decisions pertain to energy/fuel consumption and related air-quality impacts, local traffic impacts from transport trucks, water system capacity/infrastructure impacts, and effectiveness of salvaging/recycling of materials/components of the temporary supply system upon project completion.
☐	**4**	**<u>Site Dewatering Systems</u>**			+	+			+	+				+	**<u>Related Decision(s)</u>:** The need for site dewatering (common for underground construction) presents both sustainability opportunities and sustainability threats related to the manner of usage/disposal of pumped groundwater. **<u>Impacts</u>:** Pumped groundwater may be beneficial (as a replacement for potable water) for dust control, local landscaping, construction vehicle tire washing, concrete mixing water, and soil compaction moisture control, among other uses. Likewise, such water may pose a threat to local wetlands, and/or cause soil erosion and silt transport, and localized flooding. Other impacts may pertain to pumping-related energy consumption, and local noise and air quality impacts.

☐	**5**	**Temporary Buildings**	+	+			+	+		+			+	+	**Related Decision(s):** Sustainability may be enhanced with better planning and design of temporary jobsite buildings. These buildings may pertain to temporary offices for project staff, toilets for project staff and craft workers, worker dining and break facilities, warehouse and storage buildings, fabrication shop buildings, and other temporary buildings at the jobsite (such as security check points and utility equipment housings). Effective, sustainable planning and design of such facilities should address the scope of such facilities, facility location, facility size and configuration, type of materials/construction, type of utility operational systems (such as power and water systems), manner of construction, manner of demolition/removal, and manner of reuse/recycle/disposal. Innovative options may pertain to portable/modular structures, solar-powered (PV) structures, and structures with rain-water capture capability, among others. **Impacts**: The primary sustainability impacts from these decisions could affect the following: amount of energy consumed during facility operation, amount of water consumed during facility operation, amount of demolition waste from facility construction, amount of demolition waste upon disposal, transportation impacts (including related noise and air-quality impacts), and indoor air quality, among others. **Link to Other CPSAs:** CPSA #17. Pre-Assembly and Pre-fabrication of Construction Elements; CPSA #32. Energy-autonomous Pre-manufactured Reusable Facilities; CPSA #34. Collection, Remediation, and Reuse of Gray water and Storm Water; and CPSA #43. Material- and Equipment-handling Strategy.

☐	**6**	**Jobsite Usage & Layout**		+			+	+	+	+			+	+	**Related Decision(s):** Jobsite planning and design decisions pertaining to temporary site drainage, construction site roadways, storage/fabrication laydown yards, concrete batch plants, fuel storage and refueling station, worker temporary parking, and site security, among other site-usage issues. Use of local aggregate for temporary working surface (including local shale). **Impacts:** Construction site usage and layout issues can have very significant effects on wildlife habitat, worker safety, worker security, worker productivity, storm water runoff, groundwater quality, vehicle energy consumption, traffic impacts (both on- and off-site), local air quality (e.g., dust storms), and the amount of waste generated by temporary facilities that cannot be reused or re-purposed when the project is complete. **Link to Other CPSAs:** CPSA #35. Environmentally-friendly Dust and Erosion Control; and CPSA #43. Material- and Equipment-handling Strategy.
☐	**7**	**Site Waste Management**					+	++	+	+	+	+		+	**Related Decision(s):** Determining the targeted extent of waste to be recycled or repurposed. Determining the methods of collection, segregation, storage, and conveyance of waste materials, along with determining the required facilities and equipment to support these functions. Establishing or involving a local exchange to facilitate material re-use. In rare cases, a waste-to-energy operation may offer another option for consideration. **Impacts:** The most significant impacts pertain to landfill burden, local air quality, and project staff effort. Energy consumption impacts may also be significant. Local economy impacts should result from local re-use of materials. **Link to Other CPSAs:** CPSA #36. Construction and Demolition Waste Management; CPSA #37. Collection, Sorting, and Recycling of Construction Wastes; CPSA #45. Minimization of Material Surplus; and CPSA #46. Management of Material Surplus.

☐	8	**Soil & Gravel Borrow Pits**	+	+		+	+		+	+			+	+	**Related Decision(s):** Sensitive decisions pertain to the location of borrow pits and the manner of soil excavation and transport, including use and operation of heavy equipment. **Impacts**: Project managers should be attentive to the environmental impacts associated with borrow pits, such as those pertaining to storm water runoff, silt transport, groundwater impacts, soil erosion, needs for temporary transport roads, transport soil compaction effects, noise and air pollution from equipment and trucks, loss of wildlife habitat, and approach to ultimate site reclamation. Worker safety may be impacted by construction methods and use of heavy equipment.
☐	9	**Worker Transport**	++	++						+			++	+	**Related Decision(s):** Extent or scope of company-supported worker transport, such as car-pooling in company vehicles or shuttles. Selection of vehicle type(s) and size(s), fuel type, pick up locations, vehicle routes (existing or newly constructed), and hours of operation. **Impacts**: Local traffic impacts from the number of auto-trips eliminated. Energy and air impacts based on vehicle fuel efficiency, fuel type, passenger capacity, and vehicle route. Worker health and safety impacts based on passenger vehicle safety features, and vehicle route/road conditions. Parking lot size and configuration impacts. **Link to Other CPSAs**: CPSA #18. Sequence and Route Planning for Project Transport.
☐	10	**Worker Camp**	++	++	++	++	++	++	+	++	+	+	++	++	**Related Decision(s):** Many different decisions relate to the optimization of worker camp facilities and functions, such as worker transport, power, water, wastewater, telecommunications, site drainage, site lighting, dining, and sleeping facilities. Specific decisions may pertain to functions/facilities included/excluded, facility size, facility location, etc. **Impacts**: Impacts can vary significantly, with local infrastructure and community often being the most impacted elements. **Link to Other CPSAs**: CPSA #29. Sustainable Temporary Worker Camps

Appendix H. CPSA #30 Guidance: Source of On-Site Power

Description of CPSA

Consider the economic and environmental implications of various power and fuel sources (ultra-low sulfur diesel, biodiesel, LPG, LNG, CNG, solar PV, etc.), particularly in areas where the environmental impacts of grid electricity are relatively high. Seek to broaden the spectrum of possibilities by evaluating the sustainability impacts from generating temporary power on-site vs. drawing power from the existing grid. When reviewing temporary on-site power generation, be sure to consider alternative solutions such as diesel engine emission/PM reducing retrofits, hybrid-diesel generators (battery-diesel, battery-PV-diesel, etc.), portable fuel cell generators, and micro-grid/smart-grid technologies (i.e., a sophisticated/intelligent power management system that can effectively link and control the operation of multiple power generators).

Abstract

Construction services are unique in that support power is drawn on a temporary and geographically variable basis. As a result, the environmental performance of power generation technologies are often unique for construction services in comparison with other sectors of industry. A detailed case study was performed which considers the economic and environmental performance of three power generation alternatives: a conventional diesel generator, the existing electrical grid, and a battery-solar-diesel hybrid generator. For each power generation alternative, three evaluations are conducted: monetary costs and benefits, greenhouse gas emissions, and water use implications. The results provide construction managers with more robust decision support when considering sources of temporary power.

Current Status

Details regarding the CPSA #30 in-depth analysis were not available at the time this thesis was written.

Appendix I. Environmental Life Cycle Analysis for a Galvanize Line Project

Abstract

Economic input-output/environmental life-cycle analysis (EIO-LCA) models can provide insight into the environmental impacts associated with supply chain participants for a given capital project expenditure. With this method, the research team examined the environmental impacts of the supply chain of a new galvanize line mill added to an existing steel plant.

Approximately 200 line-item construction expenditures were provided by the project owner and each of these was assigned to one of 21 economic sectors represented in the 2002 economic input-output model developed and provided by the U.S. Department of Commerce, Bureau of Economic Analysis. Direct spending within these 21 sectors was simulated to estimate indirect spending, primary energy consumption (direct and indirect), and greenhouse gas emissions (direct and indirect).

The results indicate that about 40% of the project's total (direct plus indirect) primary energy consumed was used during construction (direct) and 60% of energy consumption was indirect. Similar trends are observed for greenhouse gas emissions. The study results demonstrate the usefulness and flexibility of EIO-LCA and the need to consider supply chain environmental flows when making onsite construction sustainability-related decisions.

Analysis Method

Life cycle assessment is a scientific approach to estimating the environmental life cycle of a product, process, or service [Vigon et al., 1993; Curran, 1996]. As demonstrated in Figure I.1, the environmental life cycle of a product, process, or service includes raw materials extraction through end-of-life management (e.g., waste disposal, recycling). The spirit of LCA is to reduce the shifting of environmental burdens throughout the supply chain. For example, the *indirect* impacts associated with manufacturing, processing, transportation, and waste management of a product may outweigh the potential *direct* benefits of using the product, as demonstrated by the conceptual diagram in Figure I.1.

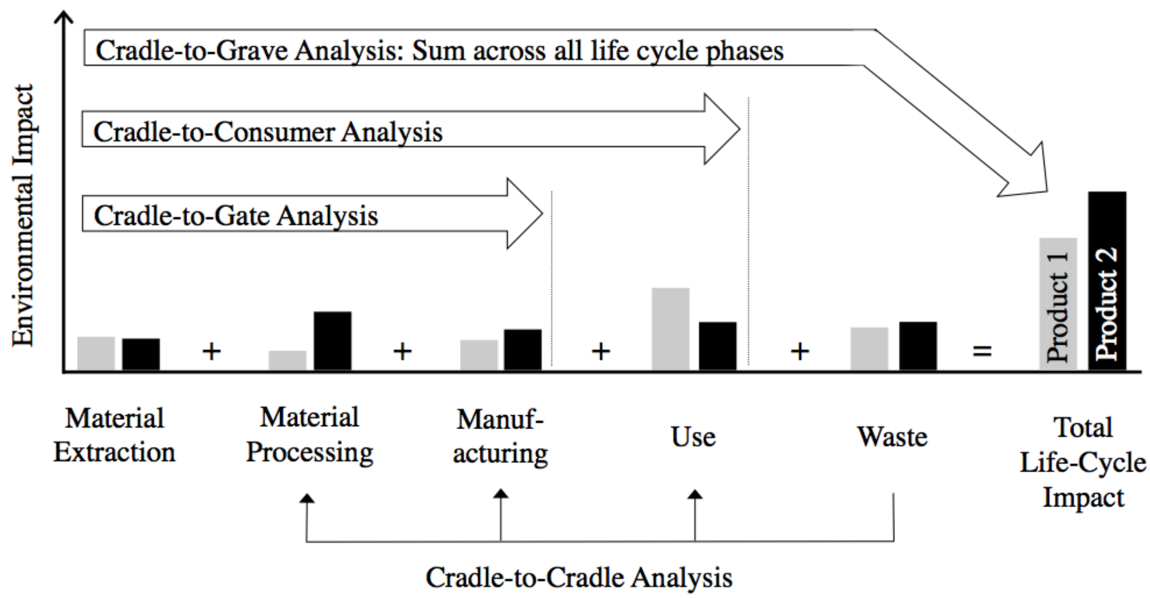


Figure I.1: A Conceptual Diagram of Life Cycle Assessment (LCA)

Figure I.1 Description: ***Diagram that shows life cycle phases on the x-axis and environmental impacts on the y-axis. Use-phase impacts alone misrepresent the total life cycle impacts of the two hypothetical products. LCA scopes can vary from cradle to either the manufacturer's gate, consumer use, or waste management, including potential material reuse and recycle loops.***

LCA methods are typically classified as either process-based or input-output (IO) based. Process-based LCA's estimate the resource inputs and environmental outputs at each life cycle stage using a mass or energy balance [Fava, 1991; Vigon et al., 1993; Curran, 1996]. This approach assimilates detailed process data and has been the basis for LCA standards [ISO, 1998]. Process-based models are often labor intensive, unable to handle circularity (e.g., co-dependence of goods "A" and "B" in their supply chains), and are prone to truncation errors, where a significant fraction of the supply chain is often ignored due to incomplete information.

The most common input-output models use economic transactions data to characterize entire economic supply chains. Data collected from the U.S. Economic Census are assembled into a matrix describing the economic transactions needed to produce goods and services for *n* economic sectors. Assuming linear production functions, these data can be used to estimate the supply chain requirements associated with any purchase in the economy according to Equation 1.

$$\mathbf{X} = [\mathbf{I} - \mathbf{A}]^{-1}\,\mathbf{Y} \qquad \textbf{(Equation 1)}$$

Where **X =** Vector of total output by sector, size *n* x 1

I = Identity matrix, size *n* x *n*

A = Technical requirements matrix, size n x *n*

Y = Final demand (decision variable or functional unit), size *n* x 1

In Equation 1, **X** is a vector of total economic output by sector given the specified final demands by sector (**Y**) and the intermediate, supply chain demands described in **A**, i.e., purchases made amongst sectors in order to produce final demands; the identity matrix is included to preserve the output generated by final demand (**Y**). Standard publications for the technical requirements matrix, **A**, apply various degrees of sector resolution, with the most detailed resolution typically being over 400 sectors [BEA, 2008].

By supplementing Equation 1 with sector-level environmental intensities (units of flows per $), the economy-wide, life cycle environmental flows from purchase, **Y**, are estimated as:

$$\mathbf{F} = \mathbf{f}\,\mathbf{X} = \mathbf{f}\,[\mathbf{I} - \mathbf{A}]^{-1}\,\mathbf{Y} \qquad \textbf{(Equation 2)}$$

Where **F =** Supply chain environmental flows associated final demand **Y**, size *n* x 1

f = Matrix with environmental flow intensities along diagonal, size *n* x *n*

The model specified in Equation 2 is typically referred to as "environmentally extended input-output analysis" or "economic input-output life cycle assessment" (EIO-LCA). Equation 2 couples supply chain modeling (Equation 1) with sector-level environmental or energy intensities (flows / $) modeled by a parameter ***f***, often referred to as an "environmental vector." The current EIO-LCA software maintained by Carnegie Mellon University (2012) includes environmental vectors for greenhouse gases, primary energy, land use, conventional air pollutants, hazardous waste, and toxic releases [CMU, 2012; Hendrickson et al., 2005]. Given that EIO-LCA models the environmental flows for production, these models are inherently limited to "cradle-to-gate" or "cradle-to-consumer" scopes. EIO-LCA models can be modified to include impacts associated with product use and disposal, but most studies use process models for these phases.

IO models overcome some of the challenges posed by process models: they avoid truncation errors by modeling all transactions upstream of a given final demand; they model empirically reported supply chain relationships (per BEA, 2008); and they model circularity. However, IO models suffer from aggregation errors because products of interest may be aggregated into economic sectors. For example, the sector "Air conditioning, refrigeration, and heating equipment" aggregates manufacturing of air conditioners, refrigerators, and furnaces into one economic sector. Thus differences in the environmental life cycle inventories of these products would have to be estimated by modifying standard IO models. IO models have also been criticized for assuming linear production functions; however, linear approximations are usually appropriate for marginal changes to supply and demand.

The literature also differentiates between *attributional* and *consequential* LCA studies. Attributional studies are intended to provide a static accounting of life cycle flows from an existing static product system, whereas *consequential* LCA approaches are more appropriate for dynamic systems that involve product compliments and substitutes ("co-products") associated with shifts in production and consumption [Ekvall and Weidema, 2004]. If the shifts in production and consumption are represented by input-output data used for model building, EIO-LCA methods can model these dynamics assuming linear responses. If not, process-based methods can be more appropriate if done carefully. Process-based analysts typically use proxy allocation data, system expansion, or some combination to estimate inventories to co-products.

Some methodological limitations can be overcome with hybrid approaches that utilize both EIO-LCA and process-based techniques. There are three general hybrid approaches: tiered hybrid, economic-input output hybrid, and integrated hybrid. A tiered hybrid approach typically applies EIO-LCA and process approaches to different life cycle stages, with some analysts integrating the use and waste management phases into the EIO model. In economic-input output hybrid modeling, broad economic sectors are disaggregated into a process model embedded into the EIO model. Joshi (1999) provides examples of both a tiered hybrid and economic input-output hybrids. In an integrated hybrid model, direct and some indirect impacts are modeled with a detailed process modeling, and more distant upstream impacts are modeled using EIO-LCA. Suh et al. (2004) notes that integrated hybrid approaches can work well for consumer products.

Galvanizing Line Fabrication Plant: A Case Study

The EIO-LCA method was applied to estimate the cradle-to-gate life cycle inventory of a steel fabrication plant constructed by ArcelorMittal. The *#6 Galvanizing Line Project* involves constructing a new heavy gauge galvanize line in an existing mill bay in Hamilton, ON. This project will replace two existing higher cost lines to allow ArcelorMittal to maintain Galvanize volumes consistent with a moderate growth market forecast. The #6 Galvanizing Line will process hot rolled pickled coils and full hard cold rolled coils for the automotive, construction and service center sectors. The line will have Galvanize and Galvanneal capabilities, horizontal accumulators, horizontal annealing furnace, a single pot, and a galvanneal furnace.

Performance expectations of the #6 Galvanizing Line project include throughput of 700,000 ton/year of line with strip thickness 1 – 4.3 mm, strip width of 610 – 1651 mm, and maximum sections of 5161 mm^2. Procurement was performed by competitive bid with ArcelorMittal Dofasco acting as the general contractor. Where possible ArcelorMittal Dofasco utilized internal resources for project management and engineering; otherwise construction engineering, construction activities, and construction management were outsourced.

Approximately 200 line-item construction expenditures provided by the ArcelorMittal Dofasco [Szkut, 2013] were each assigned to one of 21 economic sectors represented in the 2002 benchmark input-output model [BEA, 2008]. A summary of these expenditures is provided in Table I.1. The expenditures were simulated as final demand (see **Y** in Equation 1) in the 2002 EIO-LCA model to estimate the total spending (direct and indirect) and cradle-to-gate primary energy consumption and greenhouse gas emissions associated with constructing the steel plant.

Figure I.2 shows the direct and indirect spending associated with the steel plant. About 60% of direct construction expenditures were represented by three economic sectors (Nonresidential Structures Manufacturing, Fluid Process Machinery, and Metal Cutting and Forming Equipment Manufacturing). Spending in these sectors also led to indirect spending in the economy. For example, the $41M spent on *Nonresidential Structures Manufacturing* led to an additional $33M of indirect spending on other economic goods and service (resulting in a multiplier of 1.2 = $41M/$33M).

This indirect spending leads to indirect consumption of energy and GHG emissions, which are shown in Figures I.3 and I.4. Figure I.3 indicates that about 40% (about 100 TJ) of the energy consumed in the supply chain of *Nonresidential Structures Manufacturing* occurs directly during manufacturing, and the remaining 60% occurs upstream in the supply chain. Similar trends are observed in Figure I.4 for greenhouse gas emissions. These results highlight the importance of considering the environmental supply chain effects of a shift in technology, fuel, and practice during construction services.

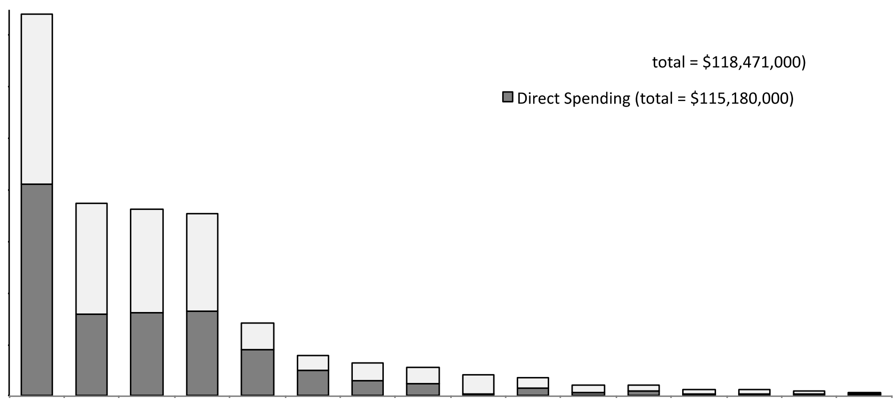


Figure I.2: Direct/Indirect Economic Activity Associated with the Construction of a $115M Steel Manufacturing Plant

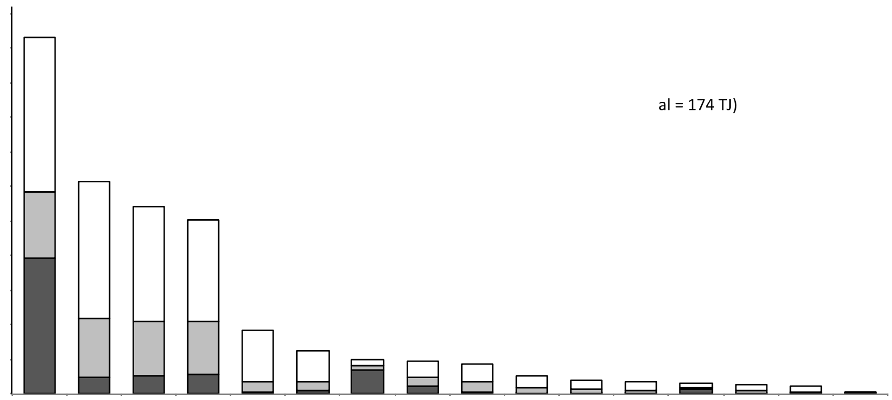


Figure I.3: Direct/Indirect Primary Energy Consumption Associated with the Construction of a $115M Steel Manufacturing Plant

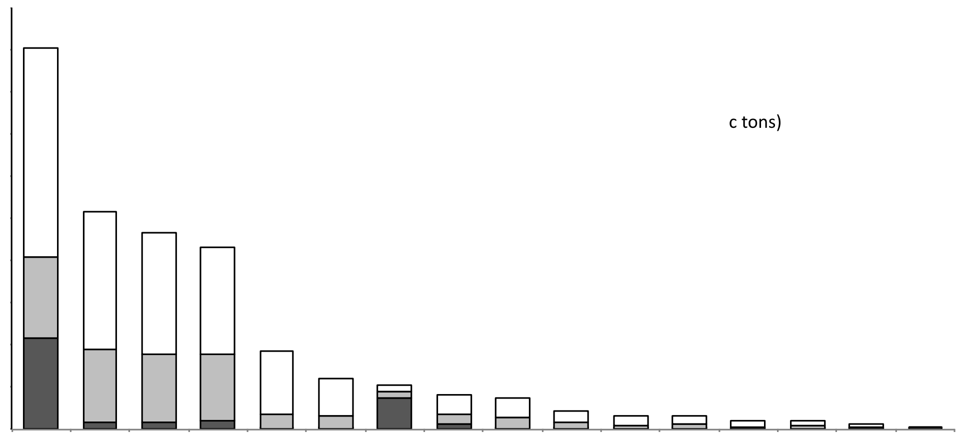


Figure I.4: Direct/Indirect GHG Emissions Associated with the Construction of a $115M Steel Manufacturing Plant

Table I.1: Expenditures for #6 Galvanizing Line Project by Economic Sector

Sector No.	Sector Name	Expenditure ($M)
333512	Machine Tool (Metal Cutting Types) Manufacturing	17.10
333992	Welding and Soldering Equipment Manufacturing	17.10
333994	Industrial Process Furnace and Oven Manufacturing	17.10
238210	Electrical Contractors	12.54
054133	Engineering Services	8.82
238220	Plumbing, Heating, and Air-Conditioning Contractors	8.34
238990	All Other Specialty Trade Contractors	7.15
236210	Industrial Building Construction	7.09
541614	Process, Physical Distribution, and Logistics Consulting Services	5.16
238110	Poured Concrete Foundation and Structure Contractors	4.16
333518	Other Metalworking Machinery Manufacturing	3.03
332312	Fabricated Structural Metal Manufacturing	2.49
238290	Other Building Equipment Contractors	2.06
331210	Iron and Steel Pipe and Tube Manufacturing from Purchased Steel	1.82
333415	Air-Conditioning / Heating Equipment; Commercial & Industrial Refrigeration	1.59

Table I.1: Expenditures for #6 Galvanizing Line Project by Economic Sector (cont'd.)

Sector No.	Sector Name	Expenditure ($M)
335313	Switchgear and Switchboard Apparatus Manufacturing	1.01
333924	Industrial Truck, Tractors, Trailer, and Stacker Machinery Manufacturing	0.90
331111	Iron and Steel Mills	0.58
337211	Wood Office Furniture Manufacturing	0.55
335311	Power, Distribution, and Specialty Transformer Manufacturing	0.52
611513	Apprenticeship Training	0.50
212231	Lead Ore and Zinc Ore Mining	0.48
238120	Structural Steel and Precast Concrete Contractors	0.45
333921	Elevator and Moving Stairway Manufacturing	0.40
335929	Other Communication and Energy Wire Manufacturing	0.35
333516	Rolling Mill Machinery and Equipment Manufacturing	0.30
334517	Irradiation Apparatus Manufacturing	0.29
561621	Security Systems Service (except Locksmiths)	0.26
334516	Analytical Laboratory Instrument Manufacturing	0.18
332410	Power Boiler and Heat Exchanger Manufacturing	0.17
333912	Air and Gas Compressor Manufacturing	0.15
238390	Other Building Finishing Contractors	0.13
238310	Drywall and Insulation Contractors	0.13
332420	Metal Tanks (Heavy Gauge) Manufacturing	0.13
054134	Drafting Services	0.10
334513	Instruments& Related Products Manufacturing	0.09
333911	Pump and Pumping Equipment Manufacturing	0.07
326122	Plastics Pipe and Pipe Fitting Manufacturing	0.07
334310	Audio and Video Equipment Manufacturing	0.07
332439	Other Metal Container Manufacturing	0.06
335312	Motor and Generator Manufacturing	0.06
333414	Heating Equipment (except Warm Air Furnaces) Manufacturing	0.05
237990	Other Heavy and Civil Engineering Construction	0.04
324191	Petroleum Lubricating Oil and Grease Manufacturing	0.04
334416	Electric Coil, Transformer, and Other Inductor Manufacturing	0.04
332212	Hand and Edge Tool Manufacturing	0.04
334417	Electronic Connector Manufacturing	0.04
326150	Urethane and Other Foam Product (except Polystyrene) Manufacturing	0.03
054136	Geophysical Surveying and Mapping Services	0.02
334111	Electronic Computer Manufacturing	0.02
339111	Laboratory Apparatus and Furniture Manufacturing	0.02
339999	All Other Miscellaneous Manufacturing	0.02
333923	Overhead Traveling Crane, Hoist, and Monorail System Manufacturing	0.01
334119	Other Computer Peripheral Equipment Manufacturing	0.01
541511	Custom Computer Programming Services	0.004

Appendix J - Sample Research Validation Feedback Template Form

RT 304 Construction Sustainability Implementation Resource
Feedback Form

Reviewer Background: PLEASE COMPLETE AND RETURN

Name		**Company**		**Date of Review**	
Contact Information					
Years of Industry Experience		**Current Job Title**			

In your review, please consider the following two questions:

Is any critical content missing? ***Are any significant corrections needed?***

You may provide feedback in any of the following ways:

1. ***Manually mark-up the document and return via mail or pdf scan/email to research team***
2. ***Use TRACK-CHANGES feature in WORD software and return the file to the research team***
3. ***Use the table below to record your specific comments, noting the page & line numbers for each comment. Add as many additional lines as needed and return to the research team as noted below.***

Please return both your background information and feedback comments/markups to the research team by Apr. 1, 2014:

Via mail: ______________________

Via email: ______________________

Questions? Please email _________ or phone him: ###-###-#### THANKS MUCH!!

No.	Page	Line	Comments
1			
2			
3			
4			
5			

Appendix K - Detailed Listing of CPSA Leveraging Conditions

Item #	CATEGORY OF LEVERAGING CONDITION	CPSA #	LEVERAGING CONDITIONS
1	**Objectives & Priority**	7, 8	Sufficient resources are available to modify schedules
2		7, 8, 50	The project schedule and budget are flexible
3		22	Project schedule allows time for selective demolition activity
4		26	The project is schedule-critical
5	**Benchmarking**	10	Sustainability performance and resource data are available
6		10	The project team is interested in evaluating and improving sustainability performance
7		54	Significant sustainability activities occurred on the project
8	**Project Scope**	2, 4, 5, 6, 13, 14, 15, 28, 40, 43	The project is large and complex
9		16	Selection of construction methods involves many complex tradeoffs
10		22, 36, 37, 46	The project involves a significant amount of demolition
11		23, 52	Project execution involves large-scale earthwork and grading operations
12		27	Project site includes existing trees and vegetation to be protected
13		27	Site congestion could result in damage to existing trees/vegetation
14		33	Building HVAC systems are installed and operational early in construction
15		44	Project fabrication and/or construction processes involve advanced technologies
16	**Project Site**	7	There is sufficient infrastructure to minimize traffic into and out of the site
17		17, 43, 51	The project site is small in size or congested
18		18, 49, 52	The project is located in an area with significant traffic congestion
19		18	Project will generate a significant amount of transport traffic
20		24	Project site is large in size

Item #	CATEGORY OF LEVERAGING CONDITION	CPSA #	LEVERAGING CONDITIONS
21		26	Project region has a significant archeological history
22		26	Project region has some endangered species
23		32	Local solar conditions are conducive to operation of facility solar-support systems
24		34	Project is located in an area where water is scarce
25		50	Projects in non-arctic or non-desert environments
26	**Stakeholder & Community Relations**	2, 6, 39	Project stakeholders and local community leaders are clearly defined and accessible
27		2	Community members have access to the Internet
28		5, 6, 13	The project owner, stakeholders, and/or local community have diverse interests relative to sustainability
29	**Project Contract**	10, 12, 15	The project team is interested in including, or has already incorporated, sustainability requirements into the prime contract
30		12	Alternative project delivery methods are available for the project
31		20	Project contract provides an incentive for contractor-proposed cost-reducing changes (such as a Value Engineering Change clause)
32		20	Project contract provides some flexibility for contractor material substitutions
33		45	The construction contract is cost-reimbursable type
34	**Procurement**	11	Projects with a few large vendors and suppliers
35		11	Projects with a significant number of suppliers and vendors who have certifications or could obtain certifications
36		11	Projects with mature suppliers and vendors
37		14	Project for national companies that specify goals for local content
38		14	Work that can be identified to go to SBEs / WBEs / MBEs doesn't require specialized expertise that might not be locally available
39		16, 39, 41	The project has high local content requirements for materials and services
40		41	International alliance-type sourcing is the contractor's standard (default) approach
41		42	Current methods of packaging/packing material result in excess waste
42		42	Owner and/or contractor have large market share and can influence shipping methods of vendors/suppliers

Item #	CATEGORY OF LEVERAGING CONDITION	CPSA #	LEVERAGING CONDITIONS
43		44	Project involves a significant amount of consumable materials to support construction processes
44		45, 46	The project team is interested in improving the accuracy of quantity take-off estimates
45		45	Project owner is not attentive to contractor procurement approaches
46		46	Many material items are purchased in large bulk quantities
47		49	Project involves many small, uncoordinated deliveries
48		49	Transport equipment tends to be oversized relative to needs
49	**Project Organization**	1, 4	The project team has experience incorporating sustainability provisions
50		1, 4, 33, 54	Project management has taken a lead role in endorsing sustainable solutions
51		1	Collaborative and communicative organization
52		3	Project organization and/or sustainability program are large in size, scope, and/or effort
53		3	Team's sustainability effort is new, fledgling, or ill-structured
54		12, 15	The owner and contractor agree to share the benefits/savings from employing sustainable solutions
55		19, 20	The contractor has experience implementing sustainable solutions/practices
56		51	Contractors and subcontractors have equipment maintenance programs in place
57	**Project Communications**	9	All parties are willing to use electronic communications and align on same electronic systems
58		9	Electronic programs / forms are available and individuals with expertise are available to run them
59		9	Projects where all parties have computers or tablets and knowledge of electronic systems
60	**Health, Safety, & Environment**	3, 5, 19, 27, 28, 54	The project is located in an environmentally/socially-sensitive area
61		17	Regional labor safety performance is below expectations
62		18, 23, 47	The project is located in an area with recognized air quality problems
63		21	Construction activities will cause a significant amount of noise and/or vibration for a lengthy duration of time
64		21	Many neighbors adjacent to the jobsite are sensitive to

Ite m #	CATEGORY OF LEVERAGING CONDITION	CPSA #	LEVERAGING CONDITIONS
			the noise and/or vibration caused by the project
65		21	The project involves a significant amount of pile-driving, rock hammering, or blasting
66		23, 35	Adjacent project neighbors are very sensitive to project-generated noise, dust, and/or equipment exhaust
67		33	Project involves buildings with human occupants
68		35	Many community residents live adjacent to the project site
69		35	The local community (and especially project neighbors) are not supportive of the project
70		52	Local jurisdiction requires clean-up of any materials placed on roadway
71	**Logistics**	50	The project has a complex logistics program
72	**Temporary Facilities**	17	A stick-built approach would involve a significant amount of scaffolding
73		25	Future projects by this contractor will very likely entail shoring, formwork, and/or scaffolding
74		25	Project design entails a substantial amount of repetition or modularity, thereby leveraging standardization of shoring, formwork, and/or scaffolding
75		25	Project involves a substantial amount of shoring, formwork, and/or scaffolding
76		28	Project involves a worker camp
77		32	Investment into reusable modular autonomous facility units may be spread over several projects
78		32	Such units are locally available for rental/leasing
79	**On-Site Temporary Power**	8	There are several options for providing electricity
80		30, 31	Regional energy costs are high and/or the local grid-sourced power has significant negative environmental impacts
81		30	Project execution requires a significant amount of electrical power
82		30	Project is very distant from the local power grid
83		31	An energy management system has not yet been implemented on the project
84		31	Workplace culture has not yet focused on energy efficiency
85	**Construction & Demolition**	22, 37, 36	Local recycling infrastructure is in place

Ite m #	CATEGORY OF LEVERAGING CONDITION	CPSA #	LEVERAGING CONDITIONS
86	**Waste**	34	Local regulatory restrictions enable the use of grey water
87		34	Project construction processes can generate a significant amount of grey water
88		36	Regional landfill dumping fees are relatively high
89		37	Other projects in the region can benefit from reuse of waste from this project
90		42	Recycling of materials is already part of the project team's culture
91		44	Project waste management efforts have been minimal
92		53	Manufactured goods that are rejected product can have alternative uses
93	**Craft Labor**	13	Sufficient number of contractors are available
94		16, 43	The project is suffering from low field craft productivity
95		29, 40	The project will have a culturally diverse workforce
96		29	Local labor supply is extremely limited
97		29	Project size is very large relative to the local labor supply
98		38, 40	The region has a shortage of skilled craft labor
99		38	Many capital projects in the area compete for skilled labor
100		38	Project will draw from a migrant labor pool
101		39	The tradeoffs associated with the different sources of employment are not obvious
102		41	The project region offers competitive sources for goods and services
103	**Construction Equipment**	19	Alternative construction equipment is available in sizes sufficient to support construction activities
104		24	Project involves a substantial amount of dunnage for temporary support of construction equipment (such as cranes)
105		24	Project involves extensive use of non-mobile heavy cranes
106		47, 51	Project involves a substantial amount of heavy construction equipment
107		47	Contractor's existing equipment fleet includes many old pieces that are not fuel-efficient
108		48	Construction equipment capacity is often much higher than needed for the task
10		48	Construction equipment fleet managers and operators

Ite m #	CATEGORY OF LEVERAGING CONDITION	CPSA #	LEVERAGING CONDITIONS
9			are mostly unaware of environmental effect of equipment operations
11 0		48	Construction equipment selection decisions are most often driven by convenient availability
11 1	**Commissioning**	53	Commissioning team is familiar with sustainability concepts
11 2		53	The owner and general contractor are interested in optimizing facility commissioning to improve the overall quality and performance of the final product

Appendix L - Detailed Listing of Common Barriers to CPSA Implementation

CPSA #	CATEGORY OF BARRIER	BARRIERS
1	Lack of information	Staff that are unaware of sustainability concepts
4		Inexperience of staff to incorporate sustainability requirements into the execution plans
5		Non-alignment in the identification of sustainability risks
6		Stakeholders are difficult to identify
10		Difficulty collecting sustainability data
12		Lack of understanding by owner or contractors about innovative delivery methods
13		Contractors in developing countries may not have the expertise or statistical basis to meet sustainability prequalification requirements
14		Structure not in place to identify MBEs / WBEs / SBEs
15		Difficulty in assigning savings to a particular proposal
19		Workers' awareness of environmental destruction is minimal
20		Lack of contractor awareness of sustainability-friendly material substitution options
21		Difficulty in predicting the significance of construction noise/vibration, and its effect on the local community
21		Lack of awareness of mitigation measures that could reduce noise and/or vibration effects
23		Contractor field engineer is not familiar with methods/technologies for enhancing earthwork efficiency
24		Inadequate information available on amount of dunnage already generated
24		Project needs for dunnage are difficult to predict
26		Lack of awareness of history of the region (relative to archeology and endangered species)
27		Inadequate information to gauge community's feelings toward potentially affected trees/vegetation
28		Inadequate information to identify sustainability impacts of temporary site facilities
29		Late and/or inadequate resource assessment of existing housing/community infrastructure, as the first step in defining craft housing needs
30		Inadequate technical support/information to decide on alternative power generation technologies

CPSA #	CATEGORY OF BARRIER	BARRIERS
33		Lack of information on immediate activities affecting future activities (such as preservation during construction)
33		Project team members are unaware of threats to air quality (such as volatile organic compounds)
35		Inadequate information on community's concern for dust
39		Difficulty in acquiring reliable information on available craft and professional workforce and associated skill levels
39		Related issues are replete with uncertainty and hidden risks
40		Lack of awareness of or poorly prepared for cultural diversity within the workforce
41		Lack of information on local suppliers and what they offer and can deliver
42		Analysis of packaging waste must be conducted first
44		Inadequate information to allow proper risk/benefit decision
45		General inattention to the amount of waste generated by a construction project
45		Many contractors have difficulty accurately estimating quantities
48		Inadequate information to make right-sizing decisions for construction equipment acquisitions
49		Coordination of transport trips is a knowledge- and effort-intensive pursuit
53		Inadequate information available before Commissioning team becomes involved
53		Inadequate information on how to recognize and optimize sustainability parameters
3	**Lack of infrastructure**	Lack of support staffing, training, funding, and other needed sustainability program resources
11		Inability of vendors and suppliers in developing countries to obtain certifications due to cost or knowledge
17		Limited availability of heavy lift equipment or other equipment to support pre-fabrication activities
18		Limited ability of the project team to receive after-hours deliveries (including limitations in storage areas)
19		Less disruptive equipment is not available
22		Local area has no recycling infrastructure/community in place
29		Lack of formal planning for camp services and facilities, including utilities, transportation, recreation, laundry, etc.
31		System needs to be customized to unique working needs and characteristics of project team
32		Project has limited access to suppliers of such units
37		Local area has no recycling infrastructure/community to support recycling activities

CPSA #	CATEGORY OF BARRIER	BARRIERS
38		Insufficient infrastructure – local educational/training facilities not available
44		Project-level recycling culture and infrastructure are not in place
46		Local infrastructure may not exist to accept materials
47		Insufficient availability of needed industry resources that support equipment operations (e.g., fueling) or maintenance, required by new, more sustainable equipment options.
48		Lack of infrastructure – availability of equipment
54		Lessons Learned system not in place; therefore difficult to disseminate findings and incorporate into future projects
1	**Limited project resources**	Sustainability is viewed as an “add-on”, rather than an integrated aspect of the project
4		Unwillingness of project owner to incorporate sustainability provisions in the execution plan
7		Schedule-driven project that requires work around the clock
8		Schedule-driven project that requires work around the clock
8		There are insufficient resources available and/or budget constraints to move work to nighttime hours
15		Contractor doesn’t see significant gain to assign and budget resources to investigate, estimate, and submit proposals to owner
16		Technical construction skills of available labor force may be inadequate
17		Limited project resources for temporary infrastructure to support preassembly activity
20		Lack of incentives for contractors to identify/recommend sustainability-friendly material substitutions
22		Project schedule pressure requires an accelerated approach to demolition
26		Limited ability for preventive- and contingency planning
27		Limited project resources to develop and implement plan
28		Limited project resources - first-cost often trumps any consideration of sustainability
30		Limited project resources to allow optional power sources to be researched
31		First-cost of system investment will deter many
32		Maintenance support will be needed to ensure that energy systems remain operational
34		First-cost of water retention system set-up can be excessive
35		Limited project resources to reduce dust emissions
37		Added expense of waste management effort and storage facilities
38		Limited project resources – lack of staff to support programs

CPSA #	CATEGORY OF BARRIER	BARRIERS
41		Time and resources required to conduct a thorough analysis on procurement sourcing
43		Limited project resources to deal with a very complex issue
43		Limited project resources to equip and train individuals on sophisticated inventory management system
46		Limited project resources may not provide for storage locations, transportation, or other activities to manage surplus
47		Limited project resources (e.g., funding) to allow for purchase or lease of "greener" equipment, if more expensive
50		Project is schedule driven and deliveries must occur at all times
52		Effort will involve both front-end cost and operations cost
2	**Outside owner/ contractor control**	Community members do not wish to engage with project management
2		Local community is not cohesive, so leadership is lacking
3		Lack of team-level sustainability commitment and leadership
5		Failure to effectively mitigate an identified sustainability risk
6		Stakeholders do not wish to participate in engagement opportunities
7		There is insufficient infrastructure and/or budget such that it is difficult to get all materials needed within non-peak traffic times
9		Unwillingness of employees, contractors, vendors, and suppliers to use electronic communications
9		Using disparate electronic tools among communicating parties
10		Unwillingness by team to perform assessment
11		Unwillingness of suppliers and/or vendors to provide documentation
12		Unwillingness by owner or contractors to use non-traditional delivery methods
13		Project owner may not want to set a prequalification requirement
14		Political resistance to "set-asides" for minority involvement
16		Local political pressure for local content may be unrealistic, given the availability of local construction skills
25		Labor unions and/or local content policies promote use of custom shoring, formwork, and/or scaffolding
34		Regulatory guidelines may not allow use of grey water
36		One or more key contracting parties is not motivated to participate in the recycling program
40		Age-old cultural hostilities among the project's workforce ethnic groups
42		Suppliers/vendors must participate in establishment of more waste-efficient shipping solutions

CPSA #	CATEGORY OF BARRIER	BARRIERS
49		Supplier buy-in to project-level logistics plans
52		Policy compliance by independent truckers may be problematic
54		Significant numbers of individuals involved with sustainability leave the project prior to the opportunity to conduct the review or meeting
18	**Unfavorable site/project conditions**	Inability to plan/integrate jobsite deliveries in a manner that reduces the number of total deliveries
23		Project design and/or contract hinders the contractor's ability to adjust earthwork quantities or placement locations
25		Project design is not compatible with modular dimensions of shoring, formwork, and/or scaffolding
36		Ineffectiveness in sorting and/or storing waste materials to be recycled
50		Project is in arctic/extreme environment that requires equipment to run at all times in order to remain operational
51		Equipment is maintained by several different contractors
51		Project is spread over a large geographic area

Appendix M. Research Team Membership

Michael Blackhurst	University of Texas at Austin
Laura Cates	WorleyParsons
Christo Gerber	Sasol Technology
Dan Gershkowitz	Dresser-Rand
Jamey Kalish	Bechtel Group, Inc.
Joshua Kneifel	U.S. Dept. of Commerce/NIST
Nancy Kralik	Fluor Corporation
James T. O'Connor	University of Texas at Austin
Don Partridge	General Electric Company
Gary Robinson	Bechtel Group, Inc.
Chad Roesti	IHI E&C International Company
Dave Stayshich	Fluor Corporation
Tom Szkut	ArcelorMittal
Neftali Torres	University of Texas at Austin

References

References by CPSA

CPSA #	CPSA Title	Source/References (bold = included in catalog/important references)
1	Leadership Team Staffing for Sustainable Projects	**[ACRP, 2012];** [Peters et al., 2011a]; **[Robichaud et al., 2011];** [Strombom, 2007]; **[Underwood, 2012];** [Yates, 2008], [Yates, 2009]
2	Community Social Responsibility Program	**[Chasey et. al. 2012]; [IPIECA, 2011]; [Peters et al., 2011a];** [Strombom, 2007]; **[Venner et al., 2004];** [Yates, 2008]; [Yates, 2009]
3	Contractor Sustainability Program and Recognition System	**[Azada et al., 2013]; [Lallande, 2008]; [NCCER, 2011]; [Peirce et al., 2005];** [Smith, 2012]; [Strombom, 2007]
4	Sustainability Provisions in Construction Execution Plans	**[Mendler et al., 2000]; [Peters et al., 2011a]; [Varghese, 2012]**
5	Sustainability Risk Management	**[Diab, 2012]; [Nijpels, 1990]; [Yilmaz et al., 2010]**
6	Stakeholder Engagement Plan	**[Chasey et al., 2012];** [Peters et al., 2011a]; **[Robichaud et al., 2011];** [Stormbom, 2007]; [Yates, 2009]; [Yilmaz et al., 2010]
7	Site Work Hour Schedule to Reduce Traffic Impacts	[ACRP 2012]; [CDA, 2009]; **[City of New York, 1999]; [Strombom, 2007]; [Venner et al., 2004];** [Yates, 2008]
8	Work Schedule to Reduce Electricity Impacts	**[Ko, 2010]; [Siler-Evans et al., 2012]; [Strombom, 2007]; [Yates, 2009]**
9	Paperless Communication and Construction Documentation	[ACRP, 2012]; [Bluebeam, 2013]; [Bluebeam, 2009]; **[CDA, 2009]; [Coddington, 2012];** [Couret, 2001]; **[Dorgan, 2011]; [Fiatech, 2012];** [McCloskey, 2012]; [Mirel, 2007]; [Peters et al., 2011a]; [Shetterly et al., 1996]; [Varghese et al., 2012]; [Zarebidaki et al., 2012]
10	Construction Team Sustainability Performance Assessment	**[CEEQUAL, 2008];** [CEEQUAL, 2013]; **[Lallande, 2008]; [Martin et al., 2013];** [Peters et al., 2011a]; **[USGBC, 2010]**
11	Verification of Sustainability Claims and Ratings	[ACRP, 2012]; **[Lu et al., 2011]; [Radzinski, 2010]; [Robichaud et al., 2011]; [TerraChoice, 2009];** [Wallace, 2012]
12	Sustainability-friendly Project Delivery Methods	**[Gormley, 2011];** [Jarrah et al., 2012]; [Peters et al., 2011a]; **[Robichaud et al., 2011]; [Syal et al., 2007];** [Underwood, 2012]
13	Contractor Prequalification Based on Safety and Sustainability Performance	**[Anderson et al., 2004]; [Jarrah et al., 2012];** [OSHA, 2008]; [Peters et al., 2011a],; **[Potter et al., 1995];** [Syal et al., 2007]; **[Truitt, 2012]**
14	Promotion of Local Employment and Skills Development	**[DFW, 2012]; [Klimley, 1997]; [RSA, 2002]**
15	Sustainability Change Proposal Clause	**[CTDOT, 2009]; [FHWA, 2011]; [Mandelbaum et al., 2006];** [Thorson et al., 1984]
16	Labor-intensive versus Equipment-intensive Approaches	**[CIDP, 2002];** [Hanna et al., 2007]; [Hanna et al., 2008]; **[Ng et al., 2008]; [Quagraine et al., 2009]; [Shen et al., 2011];** [Yates, 2009]
17	Pre-assembly and Pre-fabrication of Construction Elements	**[Calkins, 2009]; [CDA, 2009]; [CII RT283, 2013]; [MBI, 2014]; [Mendler et al., 2000];** [Ndungu, 2008]; [Peters et al., 2011a]; [Yates, 2008]; [Yates, 2009]
18	Sequence and Route Planning for	**[Chasey et al., 2012]; [Peters et al., 2011a]; [Yates, 2009]**

	Project Transport	
19	Minimization of Project's Footprint of Disruption	[CII RT250, 2011]; **[Kibert, 2008]; [Peters et al., 2011a]; [Venner et al., 2004];** [Yates, 2008]
20	Sustainable Material Substitutions	**[ACRP, 2012];** [Calkins, 2009]; [CDA, 2009]; **[City of New York, 1999]; [Mendler et al., 2000];** [Peters et al., 2011a]; **[Stain et al., 2002];** [U.S. DoE, 2008]; **[USGBC, 2010];** [Varghese et al. 2012]; [Yates, 2008]; [Yates, 2009]
21	Construction Noise/Vibration Abatement and Mitigation	**[ACRP, 2012];** [CDA, 2009]; **[City of New York, 1999];** [Peters et al., 2011a]; [Strombom, 2007]; **[Venner et al., 2004];** [Yates, 2008]; [Yates, 2009]
22	Selective Demolition versus Conventional Demolition	**[3D/International, 1999]; [3D/International, 2000]; [Kourmpanis et al., 2008]; [Napier, 2011]; [Ninmann, 2011];** [Peters et al., 2011a]; **[U.S. Army, 2003]**
23	Sustainable Large-scale Earthwork and Grading Operations	[ACRP, 2012]; [CDA, 2009]; **[CII RT250, 2011]; [Han et al., 2006];** [Peters et al., 2011a]; **[Shehata et al., 2012];** [Strombom, 2007]; **[Venner et al., 2004];** [Yates, 2008]
24	Reduction of Dunnage for Equipment Operations	**[Ratay, 1996]; [Rossnagel et al., 2009]**
25	Reusable Shoring, Formwork, and Scaffolding	[CII RT250, 2011]; **[Calkins, 2009];** [CDA, 2009]; [Mendler et al., 2000]; **[Peters et al., 2011a]; [Stain et al., 2002];** [Yates, 2008]
26	Protection of Cultural Artifacts and Endangered Species	**[City of New York, 1999]; [Kibert, 2008];** [Strombom, 2007]; **[Venner et al., 2004]**
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28	Sustainable Temporary Facilities	**[CDA, 2009]; [CII RT250, 2011]; [City of New York, 1999]; [Hageman, 2013];** [Mendler et al., 2000]; [Peters et al., 2011]; [Strombom, 2007]; [Yates, 2008]; [Yates, 2009]
29	Sustainable Temporary Worker Camps	**[EBRD & IFC, 2009]; [Franks, 2012];** [Porta-Kamp,2014]; **[Sulzberger, 2011];** [Teton Buildings, 2014]; **[Wankjek, 2013];** [Yates, 2008]
30	Source of On-site Power	[ACRP, 2012]; [Bennick, 2012]; [CDA, 2009]; [Davies et al., 2013];[EA, 2014]; [Farooque et al., 2001]; [Herzog, 2002]; [Krotz, 2003]; **[Kusakana et al., 2013];** [Leech, 2012]; [Patil et al., 2004], [Peters et al., 2011a]; [Pullins, 2010]; [Reader et al., 1999]; [Rehman et al., 2010]; **[Sammes et al., 2000]; [Scanlon, 2013];** [Scwerin, 2011]; [Solar Stik, 2013]; [Stain et al., 2002]; [Strombom, 2007]; **[Thompson, 2012]; [USDE, 2013]; [U.S. EPA, 2013]; [Venner et al., 2004];** [Voss et al., 1997]; [Wichert, 1997]; **[Wies et al., 2005];** [Yates, 2008]; [Yates, 2009]
31	Site Energy Management	[DaintreeNetworks, 2011]; **[Davies et al., 2013];** [EA, 2014]**; [Ko, 2010]; [Mendler et al., 2000]; [Rubenstone, 2010];** [Stain et al., 2002]
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34	Collection, Remediation, and Reuse of Gray Water and Storm Water	**[ACRP, 2012];** [EA, 2014]**; [Mendler et al., 2000]; [Peters et al., 2011a]; [Waylen et al., 2011]**

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36	Construction and Demolition Waste Management	**[3D/International, 1999]; [3D/International, 2000]; [ACRP, 2012];** [CDA, 2009]; [CII RT250, 2011]; [City of New York, 1999]; [Kibert, 2008]; [Mendler et al., 2000]**; [Napier, 2011]; [Ninmann, 2011];** [Peters et al., 2011a]; [Stain et al., 2002]; [Strombom, 2007]; **[U.S. Army, 2003]; [USGBC, 2010];** [Varghese, 2012]; [Wang et al., 2012]; [Yates, 2008]; [Yates, 2009]
37	Collection, Sorting, and Recycling of Construction Wastes	**[3D/International, 1999]; [3D/International, 2000];** [ACRP, 2012]; [Bennick, 2011]; [CDA, 2009]; [CII RT250, 2011]; [City of New York, 1999]; **[Howard et al., 2012];** [Kibert, 2008]; [Mendler et al., 2000]**; [Napier, 2011]; [Ninmann, 2011];** [Peters et al., 2011a]; [Stain et al., 2002]; [Strombom, 2007]; **[U.S. Army, 2003];** [U.S. DoE, 2008]; **[USGBC, 2010];** [Varghese, 2012]; [Venner et al. 2004]; [Wang et al., 2012]; [Yates, 2008]; [Yates, 2009]
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39	Expatriates versus Local Employment for Global Projects	[Belema, 2010]; **[Gray, 2013]; [IPIECA, 2011];** [Kiishweko, 2013]; **[McNulty et al., 2013]; [SHRM, 2010]**
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44	Sustainable Consumable Materials Management	**[3D/International, 1999]; [3D/International, 2000]; [Napier, 2011]; [ToolWatch, 2006]; [U.S. Army, 2003];** [Yates, 2009]
45	Minimization of Material Surplus	**[3D/International, 1999]; [3D/International, 2000]; [Agyekum et al., 2013];** [Brynjolfsson et al., 2012]; [CII RT250, 2011]; **[WRAP, 2007a]; [WRAP, 2007b]**
46	Management of Surplus Materials	**[3D/International, 1999]; [3D/International, 2000];** [CII RT250, 2011]; [Martin, 2003]; **[Napier, 2011];** [Peters et al., 2011a]; **[U.S. Army, 2003]; [WRAP, 2007a];** [Yates, 2008]
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48	Right-sizing of Construction Equipment	[CII RT250, 2011];**[EA, 2014]; [Ko, 2010]; [Peters et al., 2011a]; [Venner et al., 2004]**
49	Use of Full Transport/Equipment Capacity	**[Ko, 2010]; [U.S. EPA, 2013]; [Yates, 2008]**
50	Reduction in Idling of Construction Equipment	[ACRP, 2012]; [CDA, 2009]; [EA, 2014]; **[Ko, 2010];** [Peters et al., 2011a]; [Strombom, 2007]; **[USDE, 2013]; [U.S. EPA, 2013];**

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Details regarding the CPSA #9 guidance references were not available when this thesis was written.

References for CPSA #30 Guidance

Details regarding the CPSA #30 guidance references were not available when this thesis was written.

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