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Owners' Role in Facilitating Designing for Construction Safety

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Final Research Report
Owners' Role in Facilitating Designing for Construction Safety

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Abstract
Exploratory empirical research was performed on a promising safety intervention concept, design for construction safety (DfCS), also called prevention through design (PtD). Seventy-nine anonymous surveys and approximately 65 face to face interviews were conducted at four case study organizations. In addition, 103 online surveys were completed anonymously by members of national construction associations and organizations in 2009 and 2010. The industry survey data indicate that while the majority of owner employees had not heard of DfCS, they found the concept immediately compelling; further, they do not anticipate that potential barriers to implementing DfCS identified in the literature will prove to be significant. Key findings from the analysis of the four case studies and industry survey data regarding implementing DfCS on a project indicate that: 1) an explicit (i.e., formal) DfCS process is required; 2) proactive owner leadership and involvement are likely necessary to initiate DfCS implementation on a project; 3) owner leadership is required to set a high expectation for worker safety and health so that safety takes priority over other project criteria and to ensure general contractor and trade contractor personnel participate in the design review process; and 4) supporting tools, such as design checklists, 4-D CAD systems, and risk identification and assessment documents, facilitate the DfCS process.

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Introduction

This document reports the data, findings and recommendations of a two-year research project funded by the Center for Construction Research and Training (CPWR) under a five year competitive grant awarded by the National Institute for Occupational Safety and Health (NIOSH). The overall goal of the research was to increase the understanding of the role that owners of buildings and other constructed facilities can play in diffusing the concept of designing for construction safety (DfCS), also commonly referred to as Prevention through Design (PtD). (The two abbreviations will be used interchangeably in this report.) The ultimate outcome of the research was to communicate results that individual organizations, construction trade organizations, and NIOSH will be able to apply to minimize the exposure of construction workers to safety hazards and achieve a reduction in the injuries and fatalities experienced on construction sites.

U.S. Department of Labor statistics indicate the construction industry continues to be one of the largest and most dangerous U.S. work industries. As shown in Figure 1 below, the injury rate in construction is the highest among major U.S. industries and the death rate is one of the highest (BLS 2011). Over 1,000 construction fatalities typically occur in the U.S. annually (BLS 2011), which is associated with a considerably higher death rate than in other developed countries (CPWR 2008). The establishment of the Occupational Safety and Health Administration in 1970, the promulgation of improved OSHA standards each year, and the earnest efforts of many construction companies to establish effective safety management programs have improved the overall safety of the construction industry. However, there is clearly much improvement to be made.

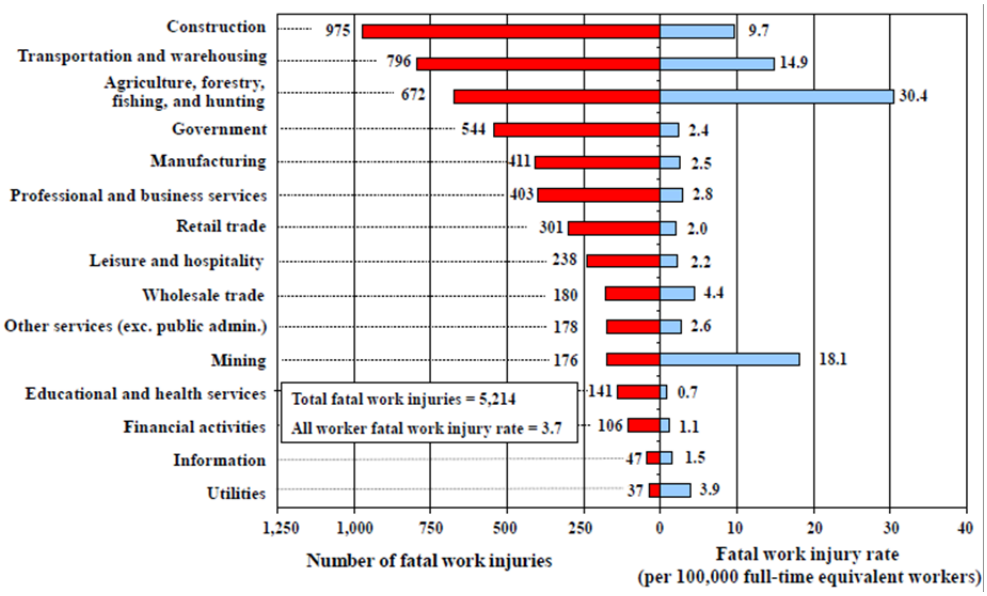

Figure 1: Number and rate of fatal occupational injuries, by industry sector, 2008 (U.S. Bureau of Labor Statistics 2010)

Several construction researchers have written that significant reductions in construction injury rates could be achieved by considering worker safety during the design of a project, not just during the construction phase (Hinze and Wiegand 1992, Gambatese, Hinze and Haas 1997, Gambatese, Behm and Hinze 2005). Legislation implemented in the U.K. in 1995 explicitly requires designers to address the safety and health risk to all parties affected by their designs and design out those risks where commercially practicable (Her Majesty 1994).

Unfortunately, in the U.S., civil engineering and architectural design professionals have traditionally either completely ignored construction worker safety in their designs or explicitly rejected the idea of contributing to worker safety. Indeed, the model contracts promulgated by the American Society of Civil Engineers (EJCDC E-500 and E-700) and by the American Institute of Architects (AIA A201 and B141) explicitly state that the design professional has no responsibility for worker safety (Toole 2002b). As a result, designers understandably fear being held liable for any safety-related activities they might undertake (Toole 2011). Moreover, most design professionals lack sufficient knowledge about construction safety to effectively perform DfCS (Gambatese, Hinze and Haas 1997, Toole 2004, Gambatese, Behm and Hinze 2005). It is highly likely, therefore, that the vast majority of architects/engineers (AEs) will not perform DfCS unless directed to do so by clients (owners and developers of buildings and other constructed facilities) or regulation. Unfortunately, as discussed in the next section, little is known about how to motivate and enable owners to assume this role.

To increase understanding within the design, construction and occupational safety communities of the role that owners can play in the adoption of prevention through design strategies, the authors of this report submitted a grant proposal to CPWR in late 2006 that proposed seven specific research objectives:

1. To identify the approximate percentage of owners who are already aware of the design for construction safety concept.
2. To identify how owners who are or become aware of the DfCS concept feel about how promising DfCS is as an intervention for improving construction worker safety and health. That is, to identify the percentage of owners who perceive the DfCS concept to be an important process for reducing construction injuries and improving the health of construction workers.
3. To identify the extent to which owners feel they can insist that the architect/engineers (AEs) they contract with for design services perform DfCS on their projects.
4. To identify the perceived and actual barriers that might prevent owners from implementing DfCS on their projects.
5. To identify the range of premiums, either in designer fees or construction cost, that owners will accept for implementing DfCS.
6. To identify how owners' opinions and acceptance of DfCS vary with organizational characteristics.
7. To create the documents needed to facilitate the adoption of DfCS by owners: a How to Guide for owners for implementing DfCS on their projects that will be made available on a webpage and include model request for proposal text and model contract text, a white paper and journal articles targeted at owners that will present the business case for DfCS.

The proposal underwent an external NIOSH review. As a result of the review comments received and subsequent telephone and email communication between Drs. Gambatese and Toole and representatives from CPWR and NOISH, the research plan was revised and Dr. D. Abowitz, Professor of Anthropology and Sociology and an expert in social science research methods, was added to the research team.

The structure of the report is as follows. First, the existing research on the PtD concept and current regulations relating to PtD in various nations is summarized. Next, the research methodology underlying this qualitative research is summarized, followed by a summary of the

data collected from four case study owner organizations. Research findings are presented, namely the similarities and differences in how PtD has been implemented by the four case study organizations are analyzed. The report concludes with specific recommendations that owner organizations should consider for implementing PtD within their organizations. The report appendices include specific data for each case study and suggested changes to standard contract documents to include PtD.

The DfCS Concept

The DfCS concept is rather straightforward: Explicitly considering the safety of construction workers in the design of a project (Gambatese et al. 2005). Using other words, DfCS is being conscious of and valuing the safety of construction workers when performing design tasks, making design decisions based in part on how the project's inherent risk to construction workers may be affected, and including worker safety considerations in the constructability review process. The authors have previously argued (Gambatese 1998, Behm 2004, Toole 2005, Toole 2007, Toole 2011) that implementing DfCS in practice is an ethical duty for engineers because it is a direct application of the first tenant of the Code of Ethics of the American Society of Civil Engineers and the National Society of Professional Engineers, which state that an engineer "shall hold paramount the safety, health and welfare of the public" (ASCE 2011, NSPE 2011).

There is a principle in quality management that quality must be "designed in." This principle also applies to safety: *Safety must be designed into a project.* A core safety tenet is that some safety management techniques are inherently more cost effective and more effective at reducing injuries than others. As shown in Figure 2, eliminating hazards through design is superior to using traditional reactive methods such as personal protective equipment (PPE).

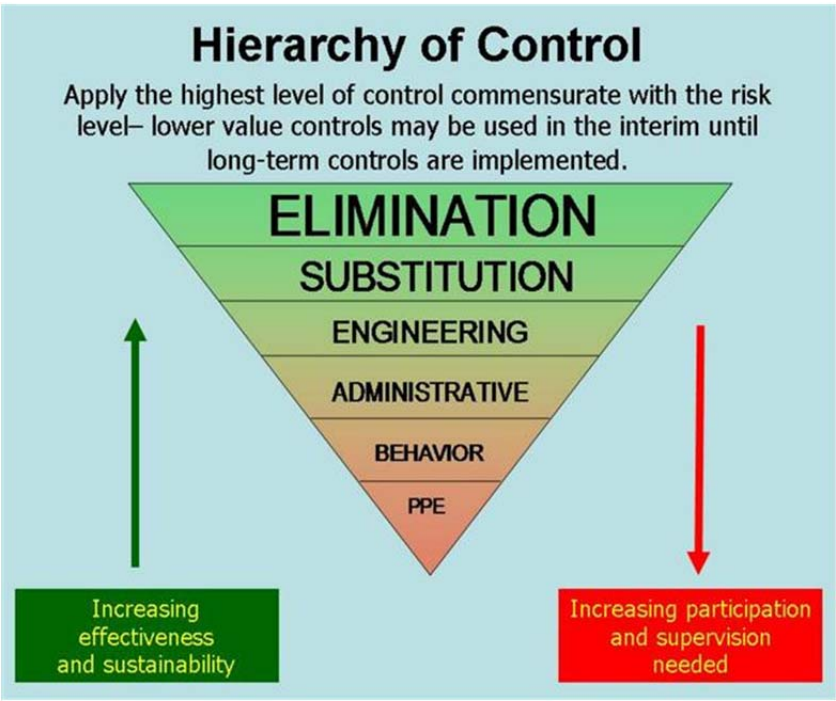

Figure 2: Hierarchy of Controls
(www.qualitysystems.com/support/display/qst/Hierarchy+of+Controls)

In addition to potential ethical duties, there are practical reasons for each party in a construction project to encourage or participate in DfCS. Subcontractors and general contractors that self-perform work have several practical reasons to encourage DfCS: it reduces accident rates, thereby reducing workers' compensation insurance rates, and increases project productivity. Designers who perform DfCS can use this fact to market themselves as progressive, team-oriented professionals. Designers who are part of design-build teams should benefit financially from the reduced accident rates experienced during construction. All owners benefit from reducing the risk that one or more construction accidents will delay project completion dates. Owners who have owner-controlled insurance programs (OCIPs) will also benefit financially from the lower accident rates that DfCS provides.

Literature and Standards Review

Previous Research on Designing for Construction Safety

Although the need for Prevention through Design (PtD) was suggested in NSC's 1955 *Accident Prevention Manual* (NSC 1995*)*, formal research on the topic in the U.S. construction industry was first conducted through a survey of design firms and firms conducting constructability reviews (Hinze and Wiegand 1992). The study revealed that less than one-third of the 23 design firms surveyed "address construction worker safety in their designs, and less than one-half of the independent constructability reviews conducted address construction worker safety." In addition, it was found that the designers who addressed construction worker safety during the design phase tended to work in design-build firms. With respect to increasing designer consideration of safety, Hinze and Wiegand suggest that designers be sensitized to the need for addressing worker safety, that a change must occur in the mindset of the design profession, and that owners must communicate to the designers the need to address safety in the design phase.

Another view of the designer's role in safety was revealed in construction marketing studies conducted in 1993 and 1994 (Hinze 1994a, 1994b). A total of 377 large owner firms, primarily those with significant construction budgets, were surveyed to determine whether the designers of their projects addressed construction worker safety in their designs. The results of both studies were very similar and revealed that 45% of the responding owners believed that their designers do not consider construction worker safety. On the other hand, a small portion of the responding owners (16%) indicated that their designers did address safety in project designs.

Input on the topic from the constructor community was gained from a study involving a survey of general contractors in South Africa (Smallwood 1996). In the study, general contractors were interviewed on a variety of construction safety issues, including the impact of the project design on safety. Fifty percent of the 71 contractors who were interviewed identified the design as an aspect or factor that negatively affects health and safety. The design was the most frequently cited factor of all of the factors identified that negatively affect safety. Almost 90% of the contractors stated that there is a need for safety education at the university or technical college for architects and engineers.

Studies have been conducted to quantitatively measure the magnitude of the relationship between design and construction safety. An initial attempt at determining the extent to which the design and the design process are linked to construction accidents was reported by the European Foundation for the Improvement of Living and Working Conditions (Lorent 1987, as cited in European Foundation 1991). In the study, Lorent reviewed construction fatalities and concluded that approximately 60% of fatal accidents arise from decisions made upstream from the

construction site. The researcher purports that these fatal accidents are due to shortcomings in design and organization of the work. More recently, as part of a study to identify where and why safety on construction sites is compromised, Gibb et al. (2003; Haslam et al. 2003) analyzed accident data in the U.K. to examine the possible contribution of design in each incident. A total of 100 construction accidents were selected and given to a group of experts to review. Validation of the experts' opinions was then conducted using the research study steering group. Following their review of each incident, the experts were asked to answer the question, "What could designers have done to reduce the risk?" By studying the experts' responses to this question for each incident, the researchers found that in 47 of the 100 incidents (47%) changes in the permanent design would have reduced the likelihood of the accidents. Based on a similar study, the researchers contend that 60% of construction accidents could have been eliminated, reduced, or avoided with more thought at the design stage (cited in Duff and Suraji 2000). Another study of an intervention to prevent musculoskeletal injuries to construction workers likewise identified antecedents in design, planning, scheduling, and material specifications as likely contributors to working conditions that pose risks of such injuries during the actual construction process (Hecker et al 2000).

A more recent study attempted to link the design for construction safety concept to construction fatalities through a review of fatality incidents in the U.S. (Behm 2005). In the study, Behm used the database of incidents investigated within the National Institute for Occupational Safety and Health's (NIOSH) Fatality Assessment Control and Evaluation (FACE) program as the data source. Of the 224 incident reports reviewed, the design was linked to the incident in approximately 42% of the cases. That is, in 94 of the 224 cases, either the design was a causal factor in the incident, a modification to the design could have reduced the safety hazard, or the design process could have been modified to prevent the incident. The researcher also identified 43 existing design suggestions that could have been implemented to reduce the hazards associated with the fatalities. In addition, the researcher developed 30 new design suggestions based on the nature of the designs and accidents reviewed. Based on the results of this research study, there is a clear and significant relationship between design and construction site safety.

In addition to these surveys, research has been undertaken to record and develop design practices that improve construction safety and to create a design tool to assist designers in the design for safety effort (Gambatese et al 1997). A review of construction industry publications and design manuals, and interviews of engineers, architects, constructors, and construction managers, led to the accumulation of design practices which, when implemented during the design phase, reduce safety hazards during construction. A database of over 400 design practices was established which provides an extensive knowledge base that can be used to educate designers about how to minimize or eliminate safety hazards in their designs. The design suggestions relate to a variety of design disciplines, project components, construction site hazards, and project systems for all types and sizes of construction projects. A computer program, titled "Design for Construction Safety Toolbox" (available from the Construction Industry Institute, Austin, TX), was developed as part of the study. The program alerts designers of project-specific construction safety hazards and suggests design alternatives to eliminate or reduce those hazards. This design tool was updated in 2010, especially the graphical interface.

Communication amongst the parties on a project and the effect of communication on the health and safety performance of a project have also been addressed (MacKenzie et al 1999). With regards to the importance of safety during the design phase, the researchers found that, except for offshore and process industries, construction worker safety is typically not considered a critical

issue by the design team. The researchers also concluded that: simplified documentation, improved communication, and improved auditing to ensure implementation could enhance safety; the detailed design phase is a critical stage for considering safety; insufficient time is currently dedicated to the implementation of safety procedures during the design phase; and more information about the project's potential safety hazards is needed during design.

These findings make apparent the need for the integration of construction knowledge into the design and the potential positive links to safety. An obstacle to the integration of construction knowledge is that designers are traditionally not trained or educated in this area and therefore it is not a topic in which they have expertise (Toole 2002a, 2004). One suggestion for overcoming this problem is to conduct a thorough risk assessment of each component of the design (Hinze et al 1999). This could be accomplished through the implementation of a constructability review process that provides direction with which the appropriate "safe" design can be created (Gambatese 2000).

Such a safety review process has been implemented and studied (Hecker et al 2005, Weinstein et al 2005). For a new semiconductor manufacturing facility in the Pacific Northwest, the facility owner sponsored the development and implementation of a safety in design process, titled "Life Cycle Safety" (LCS). The process involved structured trade contractor input during the programming and design phases of the project. A prescriptive study was conducted of the LCS process with the goals of identifying and assessing measurable outcomes relative to safety in the construction phase. Interviews and focus groups were conducted with key project participants, including design work group members who had the major responsibility for carrying out the design, and owner, designer, and contractor personnel involved in implementation of the LCS process. Additional exit focus groups were conducted of trade workers after they completed their work on the project. The research resulted in the development of 25 "cases" in which the LCS process led to changes in the design aimed at improving safety during construction. The following are examples of some of the cases:

- Add an additional basement level to the fabrication facility, and increase the height of the basement level, to provide additional room to work, facilitate the movement of materials and equipment, and eliminate "head knocker" hazards.
- Utilize a different type of floor coating on floor slabs beneath raised metal floors that allows for ease of movement across the floor slabs.
- Using smaller cable inside conduit instead of larger, insulated cable to facilitate pulling and handling of the cable.
- Increasing the parapet heights to 42 inches above the roof level to act as guardrails during construction.

The results of the case analyses indicate that recommendations for design changes are most likely to be implemented when presented early in the project life cycle. This result is consistent with other researchers' views that the ability to influence the safety of construction workers is greatest in early phases of the project. The analysis of cases additionally revealed that trade contractor input is of great value to determining what changes to make, and that design changes related to material handling are often difficult for designers to identify. The interviews and focus group responses contribute to the conclusion that increased collaboration and insertion of field construction knowledge in the early stages of project design added value to the design process. The construction knowledge provided by the trade contractors aided in exposing various safety hazards prior to commencing construction. The review of project documents and interviews of

project participants strongly suggested that the process gave a greater airing on issues and perspectives related to safety than typically occurred on projects.

A similar method proposed for enhancing the design for construction safety concept is to increase the communication between designers and construction foremen, particularly those foremen with excellent safety records (Coble and Haupt 2000). Coble and Haupt contend that foremen can make significant contributions to the design for safety effort, provided that designers recognize and harness their skills, site experience, and construction knowledge base.

A study performed nearly ten years ago focused on the viability of designing for construction safety as an intervention (Gambatese et al 2003, 2005). The research specifically aimed at providing an initial assessment of the applicability of the intervention in practice and an estimate of its effect on a project and on safety. The study involved three efforts: an examination of the OSHA Standards for Construction to determine the provisions for which designer input is mandated and recommended; the development of design details that would allow the constructor to forego implementing temporary, on-site safety measures required by OSHA; and a survey of design professionals to obtain additional insight regarding the barriers and limitations to incorporating safety in the design and the estimated impacts of designing for safety on a project.

The researchers involved in this study determined that a design professional's perception of the feasibility of the concept is generally related to the type of firm in which they are employed. Designers employed in design-build firms are more knowledgeable and accepting of the concept and less likely to believe that their liability will increase if they utilize the concept of designing for construction site safety. Furthermore, design professionals with actual construction experience are more knowledgeable and accepting of the concept. The perceived barrier most often suggested by those interviewed was that designing for construction safety interfered with the constructors' means and methods. Design professionals also listed a potential increase to project cost as the most common impact they foresaw to implementing the concept.

Even though various potential barriers exist, it was concluded that the barriers can be overcome and that addressing construction site safety in the design phase of a project is a viable intervention. In addition, there are some key changes to the industry which are vital to the successful implementation of the concept and which will have significant initial impact on both the implementation and the outcomes of designing for safety. These keys to implementation are:

- Changing designers' mindsets toward safety,
- Providing a motivational force to promote designing for safety,
- Incorporating construction safety knowledge in the design phase,
- Making designers knowledgeable about design for safety modifications,
- Making design for safety tools and guidelines available for use and reference, and
- Mitigating designer liability exposure.

As a result of continued research, and interest in and support for DfCS from many stakeholders, the American Society of Safety Engineers (ASSE) and the American National Standards Institute (ANSI) have collaborated on the development of a prevention through design standard. The standard, ANSI/ASSE Z590.3-2011 *Prevention through Design: Guidelines for Addressing Occupational Hazards and Risks in Design and Redesign Processes*, is not written to be specific to the construction industry but addresses designing for safety from a conceptual point of view for all industries. The standard provides guidance on including prevention through design

concepts within an occupational safety and health management system. ANSI/ASSE suggest that through the application of the concepts, decisions pertaining to occupational hazards and risks can be incorporated into the process of design and redesign of work premises, tools, equipment, machinery, substances, and work processes including their construction, manufacture, use, maintenance, and ultimate disposal or reuse. The standard provides guidance for a life-cycle assessment and design model that balances environmental and occupational safety and health goals over the life span of a facility, process, or product.

Occupational Safety and Health Regulations

Federal OSHA has begun to recognize the impact of the design professional on construction safety through recent regulatory changes. In the safety standards for structural steel erection, Subpart R of 29 CFR 1926, OSHA recognizes the project structural engineer of record. This title is defined to mean the registered, licensed professional responsible for the design of structural steel framing and whose seal appears on the structural contract document. As an example, OSHA now mandates a design criterion that requires all columns be anchored by a minimum of four anchor rods/bolts to ensure full support during erection. OSHA believes that it is as appropriate for the Agency to require that avoidable safety hazards be engineered out for the protection of those erecting the building as it is for local jurisdictions to set design criteria for the safety of the building's occupants (Federal Register, 2001). This position is a significant step for OSHA in recognizing the impact that a design professional can have on construction site safety.

Only a few other regulations exist within the OSHA Standards that address the impact of the designer (Gambatese et al 2003; Toole and Gambatese 2002). Tie-off connections for fall protection, for example, are often designed into the permanent structure to facilitate the attachment of lanyards. The need for designing the tie-off connections into the structure is addressed in Appendix C to Subpart M – Fall Protection, which states:

> "(h) Tie-off considerations. (1) One of the most important aspects of personal fall protection systems is fully planning the system before it is put into use. Probably the most overlooked component is planning for suitable anchorage points. Such planning should ideally be done before the structure or building is constructed so that anchorage points can be incorporated during construction for use later for window cleaning or other building maintenance. If properly planned, these anchorage points may be used during construction, as well as afterwards."

Efforts to legislate the involvement of designers in safety have taken place outside the United States. The European Union through EC Directive 92/57/EEC requires all parties involved in EU projects to address construction site safety. This effort stems from studies of construction accidents and injuries suggesting that a significant portion of such events have their origins upstream from the construction process itself and are connected to such processes as planning, scheduling, and design (Whittington et al 1992, Suraji et al 2001). EU member countries have enacted legislation in response to this directive. Great Britain, for example, has enacted the Construction (Design and Management) Regulations. These regulations place requirements for construction worker safety and health on design professionals. The effect of the CDM regulations on the design profession is that they place a duty on the designer to ensure that any design prepared avoids foreseeable risk to construction workers (MacKenzie et al 2000). Section 11 of the 2007 version of the UK's CDM regulations pertains specifically to designers. Section 11 states (Legislation 2011):

(1) No designer shall commence work in relation to a project unless any client for the project is aware of his duties under these Regulations.
(2) The duties in paragraphs (3) and (4) shall be performed so far as is reasonably practicable, taking due account of other relevant design considerations.
(3) Every designer shall in preparing or modifying a design which may be used in construction work in Great Britain avoid foreseeable risks to the health and safety of any person—
    (a) carrying out construction work;
    (b) liable to be affected by such construction work;
    (c) cleaning any window or any transparent or translucent wall, ceiling or roof in or on a structure;
    (d) maintaining the permanent fixtures and fittings of a structure; or
    (e) using a structure designed as a workplace.
(4) In discharging the duty in paragraph (3), the designer shall—
    (a) eliminate hazards which may give rise to risks; and
    (b) reduce risks from any remaining hazards,
    and in so doing shall give collective measures priority over individual measures.
(5) In designing any structure for use as a workplace the designer shall take account of the provisions of the Workplace (Health, Safety and Welfare) Regulations 1992 which relate to the design of, and materials used in, the structure.
(6) The designer shall take all reasonable steps to provide with his design sufficient information about aspects of the design of the structure or its construction or maintenance as will adequately assist—
    (a) clients;
    (b) other designers; and
    (c) contractors,
    to comply with their duties under these Regulations.

In Australia, occupational health and safety legislative frameworks continue to be developed (both nationally and at the state/territory level) to include design as an integral component of safety in the workplace (Breslin 2009). Recent amendments to legislation in Queensland, South Australia, Tasmania, Victoria, and Western Australia have been made that require designers to design buildings and structures that are safe and without risks (Breslin 2007; 2009).

While all jurisdictions place responsibilities on designers, the statutory obligations vary across the jurisdictions. The New South Wales State government, for example, requires that a management strategy exist for the design process which includes consideration, evaluation, and control of occupational safety and health during construction (NSW 2000). Since 1998, this requirement has been mandatory for all State government construction projects having a value of AU$3 million or greater or on lesser-valued projects where the government agency determines there is a high safety risk. According to Breslin (2009), in Queensland, the statutory obligations of designers and those that commission the design are only addressed. The Western Australia legislation places a statutory obligation on designers in relation to safety during the construction process and on building completion, whereas the Southern Australia legislation places responsibilities on designers only in relation to safety on building completion. Designers in Victoria will have a duty of care under the Victorian *Occupational Health and Safety Act 2004* to design buildings or structures that are to be used as workplaces without risk to the health and safety of those using the facilities. However, the designer's duty in Victoria does not include:

- the design of the construction and demolition phases of a building or the structure's life cycle;
- the design of residential dwellings that are not intended as workplaces; and
- the design of roads and footpaths (Breslin 2009).

Singapore has developed a Design Review Process called GUIDE in order to ensure safe design and eliminate construction hazards. There are five steps in the GUIDE process, as shown in Figures 3. The first step is to group together a team of project stakeholders, which are shown in Figure 4. The second step is to discuss the completed plan with designers to ensure a full understanding of drawings and calculations. The third step is to identify any risks that may be encountered during construction and determine if they could be potentially eliminated if the design were to be altered. The fourth step is to design to remove these risks from the final design for the project. The fifth and final step is to enter any design changes that affect the health and safety of construction workers into the Safety and Health Risk Register. The Safety and Health Risk Register is a document that details any risks identified during the design as well as unavoidable risks that were identified during the GUIDE process. This document is kept as a database for future reference to be used during design (Workplace Safety and Health Council 2008).

Figure 3: Singapore Guide Process Overview 1 (Workplace Safety and Health Council 2008)

Since 1993, with the implementation of the Occupational Health and Safety Act, South Africa has required designers to guarantee that their designs are safe to implement and free of potential health risks. South African Construction Regulations specify that designers must alter plans if dangerous construction methods are required in order to execute the designs. Similarly, alternative materials must be used where hazardous materials were previously specified for use in order to decrease the risk for construction workers. The designer is also required to notify the contractor on the project of any remaining, unavoidable risks (Gambatese, Behm, Hinze 2005).

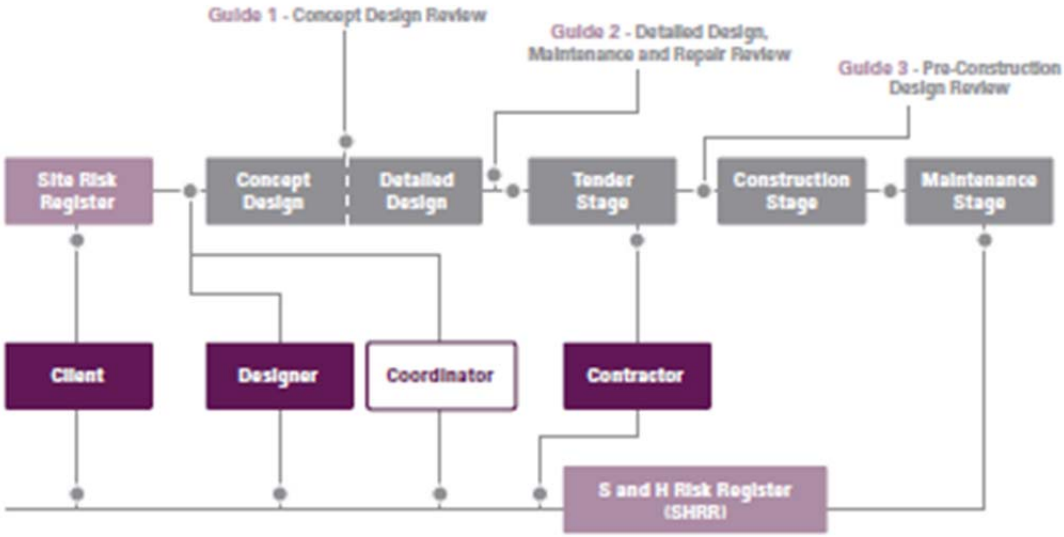

Figure 4: Singapore Guide Process Overview 2 (Workplace Safety and Health Council 2008)

The 2003 Regulations more specifically state that a designer of any structure must,

> (a) before the contract is put out to tender, make available to the client all relevant information about the design of the relevant structure that may affect the pricing of the construction work;
> (b) inform the contractor in writing of any known or anticipated dangers or hazards relating to the construction work, and make available all relevant information required for the safe execution of the work upon being designed or when the design is subsequently altered;
> (c) subject to the provisions of paragraph (a) and (b) ensure that the following information is included in a report and made available to the contractor?
>
> (i) a geo-science technical report where appropriate;
> (ii) the loading the structure is designed to withstand; and
> (iii) the methods and sequence of construction.
>
> (d) not include anything in the design of the structure necessitating the use of dangerous procedures or materials hazardous to the health and safety of persons, which could be avoided by modifying the design or by substituting materials;
> (e) take into account the hazards relating to any subsequent maintenance of the relevant structure and should make provision in the design for that work to be performed to minimise the risk;
> (f) carry out sufficient inspections at appropriate times of the construction work involving the design of the relevant structure in order to ensure compliance with the design and a record of those inspections is to be kept on site;
> (g) stop any contractor from executing any construction work which is not in accordance with the relevant design;
> (h) conduct a final inspection of the completed structure prior to its commissioning in order to render it safe for use and issue a completion certificate to the contractor; and
> (i) ensure that when preparing the design, cognisance is taken of ergonomic design principles in order to minimise ergonomic related hazards in all phases of the life cycle of a structure (South African Dept. of Public Works 2003).

Government and Industry Activities on Designing for Construction Safety

In addition to promulgating federal safety standards that are related to DfCS, federal governmental efforts related to designing for safety have occurred, namely activities associated with OSHA and NIOSH. Comments made in 1999 by H. Berrien Zettler, then Deputy Director of OSHA's Construction Directorate, support the notion that the Agency recognizes the impact that a designer can have on construction site safety. According to Zettler, "OSHA believes that much could be done to improve safety and health on the worksite if we could get designers, engineers, and architects to pay attention from the beginning and design into blueprints measures that would lead to a safer workplace, to think of a construction process and design for that as well as for end use…" (Korman 1999). In 2005, OSHA began hosting quarterly meetings of a workgroup, focusing on DfCS, composed of national organizations that had alliances with OSHA. Initial members included:

- American Society of Civil Engineers-Construction Institute
- American Society of Safety Engineers
- Independent Electrical Contractors
- ADSC: International Association of Foundation Drilling
- Laborers Health and Safety Fund of North America
- Mason Contractors Association of America
- National Fire Protection Association
- National Institute for Occupational Safety & Health
- Sealant, Waterproofing and Restoration Institute
- Washington Group International (now a subsidiary of URS Corp.)

The workgroup's activities included jointly creating a PowerPoint presentation that can be used to introduce the PtD concept, advising Dr. Toole in creating a website (www.designforconstructionsafety.org), establishing an action agenda to further the design for safety initiative, and arranging for presentations at national conferences, including the International Association of Foundation Drilling conference, the American Institute of Steel Construction conference, the American Society of Safety Engineers conference, the VPPPA conference, the Construction Users Roundtable conference, the National Safety Council Conference, the Construction Safety Council conference, and the OSHA On-Site Consultation conference. Beginning in 2009, this workgroup was merged with an OSHA Alliance Roundtable workgroup focusing on fall protection. The joint workgroup has produced several documents that illustrate opportunities for PtD in several specific contexts.

NIOSH has been particularly active in researching and promoting PtD. In 2003, NIOSH was one of the sponsors of a symposium focusing on PtD in construction held in Portland, Oregon (Hecker et al 2004). At the September 2006 meeting of the NIOSH NORA Construction Sector Council meeting held in Morgantown, WV, DfCS was identified as one of the top ten research priority areas. A workgroup, Co-Chaired by Dr. Toole, consisting of NIOSH and industry members of the Council, was formed to identify specific research goals and mechanisms. The workgroup's paper was incorporated into the NORA National Construction Agenda (www.cdc.gov/niosh/nora/comment/agendas/construction/pdfs/ConstOct2008.pdf) and increasing the use of PtD was identified as Strategic Goal 13.

In 2007, NIOSH convened a workshop in Washington, DC that focused on PtD in eight industry sectors, including construction. Several hundred individuals attended this workshop, including

approximately 75 individuals who participated in a one-day breakout track on construction. NIOSH formally launched a national PtD initiative at this workshop (www.cdc.gov/niosh/topics/ptd) and in 2011 held another successful multiday workshop in Washington, DC on PtD across multiple industry sectors (www.cdc.gov/niosh/topics/ptd/a-new-way).

In 2011, the American Society of Safety Engineers (ASSE) announced the approval of the American National Standards Institute (ANSI)/ASSE standard, "Prevention through Design: Guidelines for Addressing Occupational Risks in Design and Redesign Processes" (Z590.3). This standard provides guidance on applying PtD concepts in any occupational setting and does not focus on the construction industry. ASSE's Construction Division has included articles on PtD in several issues of its quarterly publication, *Blueprints*.

The involvement of the American Society of Civil Engineers (ASCE) in the growth of PtD has been controversial. ASCE's policy on construction site safety (Policy Statement #350) states that "improving construction site safety requires attention and commitment from all parties involved." The policy also states ASCE's opinion that engineers shall have responsibility for "recognizing that safety and constructability are important considerations when preparing construction plans and specifications." In 2003, ASCE's Construction Institute formed an alliance with OSHA to further the safety and health of construction workers. The alliance agreement stated that the Construction Institute and OSHA will work together to develop and deliver training and education programs, perform case studies and publicize the results to industry stakeholders, participate in forums and roundtable discussions on construction safety issues, and focus on incorporating safety and health issues into the construction process. One of the authors (Dr. Toole) was ASCE's primary contact with OSHA and met quarterly with OSHA staff, including on the OSHA Alliance Roundtable DfCS working group activities summarized earlier. ASCE's alliance with OSHA was renewed in 2005 but not renewed in 2007.

In 2007, the report authors submitted a proposal to ASCE to establish a Prevention through Design Committee within ASCE's Construction Institute. This proposal was approved and the authors served as Chair and Vice Chair. Shortly after the Committee began holding conference call meetings, some individuals on ASCE's Board of Direction and leaders within the American Council of Engineering Companies (ACEC) began expressing concern about the liability and other issues associated with the PtD concept (Toole 2011). The Committee was eventually dissolved and ASCE currently has no association with PtD.

Research Methodology

The authors decided the best methodology to achieve the seven research objectives listed at the beginning of this report would be a combination of quantitative surveys and qualitative case studies. Specifically, an online survey of individuals associated with seven national owner organizations was utilized to achieve the first six research objectives, and case studies of four large owner companies were completed to gain knowledge to allow the creation of a How To Guide associated with the seventh research objective. Both research methods required that Drs. Gambatese and Toole complete their respective institution's human subjects training. Dr. Abowitz had already received such certification. The research plan and instruments were approved by Bucknell's Institutional Research Board (IRB). Appendix 1 provides the documents reviewed by the IRB.

Case Studies

The four case study organizations include a power generating corporation, an integrated energy corporation, a microchip manufacturer, and a hospital construction project. Collectively, the four organizations can be considered to be a purposive sample as one of the reasons they were chosen was that Drs. Gambatese and Toole had prior interactions with at least one employee in the organization. Specifically, Dr. Gambatese had visited the headquarters of the power generating company and the microchip manufacturer several years earlier as their DfCS programs were being launched. Dr. Toole had been contacted by an employee of the energy company who had visited www.designforconstructionsafety.org and by an employee of the general contractor working on a hospital project after seeing Dr. Toole make a DfCS presentation at a conference. While each organization had a demonstrated interest in DfCS (and would therefore be more likely to respond positively to the request to participate in the research), they were in different stages of adopting DfCS and differed substantially in many characteristics unrelated to DfCS.

For each organization, the authors' contact was asked if their organization might be willing to serve as a case study for the research project and was sent the proposed case study details included in Appendix 2. As noted in this document, each case study was initially expected to allow the authors to interview 6-12 employees and to review various DfCS documents. It was later decided that the research objectives could be better achieved if a larger sample of employees completed the survey that was designed to be sent to members of national owner organizations. All four case study organizations agreed to participate in the survey portion of the research as well as the interview portion.

Once the contact secured the necessary approvals to have the organization serve as a case study, the contact was asked to have 20-50 employees in their organization (or in the case of the hospital project, associated with the project) complete an anonymous survey. The survey was created based on a prior survey that had been drafted and reviewed by the members of the ASCE PtD Committee. The draft was substantially modified to reflect review comments by Dr. Abowitz, who has survey expertise. Eight demographic questions were deleted because the researchers could obtain the information, which was the same for all employees of the same company, from other sources. The final survey (see Appendix 3) included 26 questions and was completed anonymously by volunteer participants.

The survey associated with the microchip manufacturer and power generator was completed by having the contact mail MS Word files containing the survey to potential participants, who then completed the survey (if willing) and emailed the completed survey back to the contact. Hardcopies of the completed surveys were then given to one of the authors, who knew neither the identities of who was asked to complete the survey nor the identities of who actually submitted the surveys. The survey associated with the energy company and the hospital project was completed by having the contact email a www.surveymonkey.com URL to employees, who then completed the survey anonymously online if willing. Neither the contact nor the authors were able to identify who actually completed the survey but the contact was told how many surveys were completed within their organization. The results of the survey will be discussed in the Findings section of this report.

Interviews within each case study organization were scheduled by the contact and occurred over 1-2 days at the organization's office or project site between August 2009 and April 2010. The interviews can be considered voluntary in that the person scheduling the interviews had no formal power over the interviewees. Conversations between the authors and contacts indicated

that if a potential interviewee did not wish to be interviewed, he or she merely had to indicate she was not available that day. As discussed further in the Conclusions section, this fact makes it impossible to rule out self-selection sample bias. Interviewees included design engineers, construction management staff, construction safety staff and constructors. With the exception of the hospital project, all interviewees were employees of the case study firm. All interviews used the same interview script (see Appendix 4). Whether one or both authors participated in each interview varied with the organization, the number of interviewees scheduled by the organization contact, and the length of time scheduled for each interview (typically 30 minutes). With some interviewees, the allotted time was exceeded before all interview script questions could be asked. All interviews at the microchip manufacturer were completed by Dr. Gambatese. All interviews at the energy company were completed by Dr. Toole. At the power generator and the hospital project, some interviews were completed jointly by Drs. Gambatese and Toole and some interviews were completed by just one of the authors. A description of each set of interviews (i.e., the positions of those interviewed and a summary of the findings) is provided in the Findings section.

The majority of documents related to each case study that the authors received to review were provided in hardcopy form during the visit or emailed shortly after the interviews. With the exception of the power generating firm—which had an extensive set of DfCS-focused documents—the case study organizations did not have documents explicitly associated with DfCS. Instead, the documents reviewed by the authors included policies, procedures, process checklists and decision tools related to the overall project design and construction process, often focusing on risk management and/or occupational safety. A description of each set of documents reviewed is provided in the Findings section.

Details about the organizational context and research process associated with each case study are provided in Appendices 5-8.

Industry Survey

In addition to the case studies, an on-line survey of owner organizations throughout the construction industry was conducted. The objectives of the survey were to ascertain and assess the experiences and perspectives of typical owner organizations in regards to the DfCS concept and practice, and to determine whether the findings from the case studies were representative of the overall construction industry. The survey differs from those conducted in past research in that it focuses on owner organizations as opposed to design and/or construction organizations. While the case study interviews focused to a large extent on an owner firm's existing DfCS process or related processes, the industry survey provided an opportunity to obtain data applicable more to the overall DfCS concept. In addition, the industry survey allowed for comparisons across industry segments, firm sizes, geographic region, firm type, and other industry and firm characteristics.

The process undertaken to conduct the survey included identifying a target audience, developing a survey questionnaire, pilot testing and modifying the survey questionnaire as needed, distributing the survey questionnaire, and collecting the survey responses. The audience targeted for the survey consisted of representatives of firms/organizations that are members of the following associations:

- Construction Industry Institute (CII)
- Construction Users Roundtable (CURT)

- Associated Owners and Developers (AOD)
- Building Owners and Managers Association (BOMA)
- Construction Owners Association of America (COAA)
- American Society of Civil Engineers – Construction Institute (ASCE-CI)

The membership of each of these associations contains owner organizations that interact with the construction industry in the construction of capital facilities. The memberships are diverse in their firm size, type, location, and industry segment. In addition, personal contacts of the researchers within the following owner organizations were identified to solicit their participation in the survey:

- Government Service Administration (GSA)
- Department of Energy (DOE)
- Department of Defense (DOD) facilities management offices, including the Naval Facilities Engineering Command and Army Corps of Engineers
- Pennsylvania state department of transportation (PennDOT)
- Oregon state department of transportation (ODOT)

The survey was conducted using an on-line questionnaire similar to that prepared for the case studies. Starting with the case study questionnaire, the researchers developed a general industry survey that contained the same questions. The survey introduction and instructions were slightly modified to make the survey applicable to the general industry and eight demographic questions relevant to the research objectives were added, as was the case for the hospital project case study. To pilot test the questionnaire, the researchers sent it to three personal contacts at owner organizations for their review and comments. Recommended changes from the pilot test were incorporated into the questionnaire. The survey questionnaire was then placed on-line using the survey tool SurveyMonkey (http://www.surveymonkey.com/). A copy of the survey questionnaire is available in Appendix 9. In order to facilitate categorizing the responses, six different identical versions of the on-line questionnaire were created. A version was created for each of the following groups:

- Construction Industry Institute (CII)
- Owner associations (CURT, AOD, BOMA, and COAA)
- Federal agencies (GSA, DOD, DOE)
- American Society of Civil Engineers – Construction Institute (ASCE-CI)
- Pennsylvania state department of transportation (PennDOT)
- Oregon state department of transportation (ODOT)

Distribution of the survey questionnaire was done via e-mail. A recruitment e-mail was created that described the research study and the survey, and included a link to the on-line survey. The text of the recruitment e-mail is shown in Appendix 10. The e-mails were sent directly to the contacts within each association and/or organization. The respondent was asked to both complete the survey and, where applicable, distribute it to co-workers or to their members firms (CII, CURT, AOD, BOMA, and COAA).

SurveyMonkey records the survey responses and makes them available in an MS Excel file. At the completion of the survey, the Excel files for each of the six versions of the questionnaire

were downloaded for analysis. Descriptive statistical calculations were conducted within Excel, and additional statistical analyses were conducted using a statistics analysis program (S-plus).

Based on the target audience as described above, e-mails containing a request to complete and distribute the survey were sent to the following contacts:

- Owner associations: CURT (1); BOMA (1); AOD (1); COAA (120 on COAA e-mail distribution list)
- Federal: US Army Corps of Engineers (1), NASA (1), DOE (4), GSA (2), VA (1)
- ASCE-CI (1 and included in ASCE-CI newsletter)
- CII-Safety Community of Practice (1)
- PennDOT (1)
- ODOT (37, with 2 returned as undeliverable)
- Private owner firms (20)

CURT, BOMA, and AOD elected not to distribute the survey e-mail to their membership, while COAA sent it out to the 120 members on its e-mail distribution list. Similarly, ASCE-CI included an announcement about the survey in their monthly newsletter encouraging members to complete the survey. While one e-mail was sent to PennDOT, the recipient passed it along to other PennDOT employees to complete. This was similarly done by the recipients at some of the Federal agencies (GSA, USACE, and DOE). The researchers were not informed of the number of people to which these recipients sent the e-mails. Therefore, while the total number of confirmed recipients is 190 as indicated above, the actual number is greater. When no response from the initial recipient was received, the researchers sent out repeat e-mails solicit their participation.

Data, Analysis, and Findings

This section of the report presents the data, analysis, and findings from the case studies and industry survey. First, findings for each case study are presented for the survey data, the interview data, and for the collective data sets. Next, findings from the industry survey data are presented. Finally, findings from the aggregated survey data—including both the case study survey data and the industry data survey—are presented.

Case Study Data and Findings

Hospital Project Findings

Details about the survey and interviews of individuals associated with the hospital project case study are provided in Appendix 5.

Hospital Project Survey Data Summary

Appendix 11 contains an MS Excel spreadsheet summarizing the survey data. This spreadsheet was generated by www.surveymonkey.com, which was used to collect the data. As shown in this document, the initial survey questions were associated with awareness and attitudes towards DfCS. For question 1, 65% of respondents had never heard of DfCS while 7% uses it routinely. Attitudes towards DfCS (question 2) were highly positive: 85% said they would consider trying it or will likely try it. When asked how construction worker safety and health is addressed in design (question 3), only a few respondents indicated that it wasn't addressed. Sixteen percent reported that DfCS is part of the AE scope of work, 28% use design checklists, 64% use constructability reviews, and 32% use in-house design guides. When asked in question 5 what

motivates or would motivate them to implement DfCS, all of the possible responses were checked by at least half of the respondents. It was noted that the percentage of respondents who indicated they would be motivated by improved worker safety and health was the same as the percentage who marked improved construction quality (85%). When asked to rank project priorities (question 14), quality (2.6), cost (3.0) and schedule (3.7) were ranked highest by the overall set of respondents out of the eight choices given. Construction worker safety and facility user safety were the next ranked priorities, each averaging approximately 4.0 out of 7.

Many of the survey questions addressed potential barriers to DfCS. Respondents varied widely in their perceptions about how easy it would be to modify AE contracts to have them perform DfCS. For example, while 23% stated it could not happen, 33% stated it would be easy to make the modifications. Just under 70% of respondents favored such modifications while 12% would not support them (question 7). Similar variation was associated with the question (8) about the level of AE resistance to performing DfCS. While 13% believe AEs will never agree to perform DfCS, 68% reported that some or all of the AEs they work with will agree to perform DfCS. With regards to whether AEs are capable of performing DfCS (question 9), the vast majority of respondents believe that AEs could learn to perform DfCS with assistance. The percentage of respondents who reported AEs could never learn enough to perform DfCS was the same low percentage (4%) as those who feel AEs are already capable of performing DfCS. When asked in question 10 "If a typical owner was reasonably confident that DfCS would reduce total project costs (design and construction) by 2%, he or she would likely be willing to pay A/Es up to ____% more in design fees to perform DfCS," answers ranged from 0-30%, with the average being 5.6% (and a standard deviation of 8.3). Only 4% of respondents indicated that increased AE fees would prevent DfCS from ever being performed. With regard to DfCS increasing their organization's liability, 58% reported it would decrease liability while 31% reported it would increase their liability exposure (question 12). It was noted that every respondent who indicated DfCS would increase their organization's liability exposure was an employee of an AE, design-builder or contractor, not of an owner organization.

When asked in question 15 to identify how key project results would change if a substantial portion of the industry elected to perform DfCS, the majority of respondents indicated construction worker injuries and lawsuits against owners would decrease while design costs, construction quality and the reputation of AEs in society would increase. Opinions on other project results were mixed, as shown in Table 1 below.

Table 1. Impact of DfCS on Project Outcomes – Hospital Project (n = 26)

Outcome	% of Respondents			
	Decrease	No Change	Increase	I don't know
Construction injuries	92%	8%	0%	0%
Design costs	0%	24%	64%	12%
Construction costs	40%	28%	28%	4%
Total costs to owner	28%	40%	28%	4%
Design durations	0%	54%	46%	0%
Construction durations	36%	56%	4%	4%
Total durations	28%	44%	28%	0%
Construction quality	8%	20%	72%	0%
# of lawsuits against owners	84%	12%	0%	4%
# of lawsuits against AEs	60%	20%	12%	8%
Reputation of AEs	4%	28%	60%	8%

Hospital Project Interview Summary

Appendix 12 provides a compilation of the answers given during the structured interviews (n = 26). A summary of this document is provided below.

There is no formal DfCS program on this project but opportunities for making the design safer for construction workers are routinely identified and implemented. Most project participants are eager to identify DfCS opportunities because safety is implicitly one of the top project priorities and some project participants consider safety part of constructability. Safety is not explicitly acknowledged to be the #1 priority on the project, but it is always given priority over cost, schedule and quality when it is explicitly weighed against them.

Trade contractors recognize that ensuring a high level of safety is a good business practice, and are the primary drivers of DfCS on this project. They are most interested in making sure it occurs and contribute the most knowledge to the DfCS process. The GC/CM also encourages DfCS and contributes substantial field operations knowledge to the process. The owner has not encouraged DfCS to be performed and cannot contribute any helpful information. In general, the project designers have not sought DfCS input, but have not resisted DfCS suggestions that have been made. Some of the AEs have reasonable knowledge of field operations but none have DfCS expertise.

The owner indirectly enabled DfCS to be performed by establishing the project as an Integrated Project Delivery (IPD) project. The opportunities for collaboration provided by the IPD process are critical for enabling DfCS on this project. Without an IPD process, the trade contractors—who are driving DfCS on the project—would not have the ability to interact with designers to influence DfCS. Sometimes DfCS occurs as a direct result of the use of Lean Construction decision tools, namely A3s and Choosing by Advantages. These tools require a thorough, methodical consideration of all criteria relevant to a design decision. These tools have sometimes, but not always, led to safety being considered when a design decision is being made. DfCS decisions are also made based on informal face-to-face discussions not connected with a Lean Construction process. DfCS opportunities sometimes occur as a by-product of choosing to use a prefabricated assembly. Such assemblies are chosen because they offer cost and time savings, but safety benefits often result as well. Structural phases (steel and concrete) are the construction phases that have received the most attention, probably because they are the most dangerous. Mechanical features have also received a lot of attention due to discussions of prefabrication opportunities and risks.

Most project participants feel that more DfCS opportunities would be identified and implemented on the project if a formal DfCS program were established. AE's lack of DfCS knowledge and concern about liability would hinder the effectiveness of such a program. Having a formal DfCS program would help achieve the goals for having an IPD process: increasing project collaboration in order to achieve lower cost, higher quality and safer construction. DfCS would also improve the reputation of the industry.

Hospital Project Findings from Survey and Interviews

Attitudes towards the DfCS concept were overall very positive. DfCS is seen as leading to fewer injuries, decreased cost and improved quality of construction and the reputation of the construction industry. While there is no formal DfCS program on this project, DfCS opportunities are identified and implemented through both organic, unstructured processes and structured lean construction practices. While the survey data indicate that construction worker

safety was given lower priority than cost, schedule and quality, several interviewees stated explicitly that worker safety would trump all other decision criteria. Moreover, the survey data indicate that approximately one-third of respondents reported worker safety is addressed in design using design checklists and in-house design guides. Approximately two-thirds of respondents reported safety is addressed through constructability reviews. AEs' lack of knowledge about construction safety and DfCS, and AEs' concern about liability and the need to increase design costs, were acknowledged to be significant barriers to the use of DfCS on other projects. The survey did not address the topic, but the interviews very clearly indicate that the designer-constructor collaboration during design enabled by an IPD process is critical for effective DfCS to occur.

Microchip Manufacturer Findings

Details about the survey and interviews of individuals associated with the microchip manufacturer case study are provided in Appendix 6.

Microchip Manufacturer Survey Findings

A total of seven survey responses were received, four from the Owner firm and three from the CM firm. Other demographic information about the respondents is not available as the surveys are anonymous. Appendix 13 contains the MS Excel spreadsheet that summarizes the survey data.

Nearly all of the respondents (85%) implement DfCS routinely or on a limited basis (question 1), and all have a positive attitude toward DfCS and are willing to implement it (question 2). Similarly, almost all respondents (86%) indicated that it is part of the AE contract (question 7). Design checklists, constructability reviews, and in-house design guides are all used equally as part of DfCS (question 3). The respondents had mixed responses regarding the importance of DfCS to safety on the jobsite (question 4). Fifty-seven percent felt that DfCS has about the same importance as other safety programs, while 43% believe that it is significantly more important to safety. In terms of motivation (question 5), the respondents indicated that the primary motivators were: improved construction safety and health (21%), improved facility O&M safety and health (21%), improved construction quality (21%), and enhanced reputation (15%).

In terms of barriers, 71% of the respondents indicated that the contract is not a barrier as no changes would be needed (question 7). Of those familiar with standard design contracts (4 of the 7 respondents), three (75%) indicated that they would support changes to the standard documents to include DfCS (question 8). Most of the respondents (71%) felt that AE's would gladly perform DfCS (question 9), and that they would need some assistance (71%) (question 10). The majority of respondents (57%) felt that while there may be increased AE fees to implement DfCS, the additional fees could be justified to higher management (question 12). All of the respondents felt that implementing DfCS would decrease their liability exposure (question 13). It should be noted that the respondents were only from the Owner and CM firms (no design firms).

In terms of their organization's priorities on a project (question 15), the average ranking of seven priorities (1 = highest rank, 2 = second highest rank, and so forth) was as follows: construction worker safety and health – 1.14, facility user safety and health – 2.86, maintenance worker safety and health – 3.00, project cost – 3.57, quality of the final product – 3.57, project schedule – 3.86, and aesthetics – 6.33.

Lastly, in terms of impacts to different project outcomes (questions 16), the responses were as shown in Table 2 below:

Table 2: Impact of DfCS on Project Outcomes – Microchip Manufacturer (n = 7)

Outcome	% of Respondents			
	Decrease	**No Change**	**Increase**	**I don't know**
Construction injuries	100%	0%	0%	0%
Design costs	0%	50%	50%	0%
Construction costs	50%	33%	17%	0%
Total costs to owner	50%	17%	33%	0%
Design durations	0%	17%	67%	17%
Construction durations	50%	17%	17%	17%
Total durations	33%	17%	33%	17%
Construction quality	20%	0%	80%	0%
# of lawsuits against owners	67%	0%	0%	33%
# of lawsuits against AEs	67%	0%	0%	33%
Reputation of AEs	0%	0%	67%	33%

Microchip Manufacturer Interview Findings

Appendix 14 provides a compilation of the answers given during the structured interviews. A summary of this document is provided below.

The Microchip Manufacturer has developed a DfCS process called Life Cycle Safety (LCS) which it implements on all of its large capital improvement projects. A description of the LCS process is provided in Appendix 15. It was consistent throughout the eight interviews that the Owner is the driver of the LCS process and is motivated to ensure an injury-free environment during all phases of the facility's lifecycle. Those interviewed are motivated for the same reason, and also want to meet the Owner's goals. In regard to whether the LCS process would be implemented if the Owner did not drive it, the responses were mixed but most people felt that it would not happen if the Owner did not push it. A minority felt that it would be implemented as a result of the CM's constructability efforts.

The LCS process is initiated on projects through the design contract with the AE. The AE's scope of work includes implementation and oversight of LCS on the projects. All of those interviewed were knowledgeable about the process during the project which consists of LCS walks around the site, design document reviews ("page turns"), a review of the LCS checklist, and LCS workgroup meetings. Opportunities for revising the project's design to improve safety are generated through each of these activities. Information and suggested design changes are discussed in the meetings and shared via e-mail. The decision to make a change is made sometimes collectively by the project team and sometimes by the Owner lead for the affected discipline. Those interviewed feel that the reviews and meetings are best held at 30-60% completion of the design. This allows for enough design to be developed but is not too late to change the design. Those providing input to needed design changes are primarily CM and trade contractor representatives. Owner representatives can provide helpful input depending on their experience. Designers provide less input on construction hazards but are integral to determining design issues.

When comparing alternative designs, the majority of interviewees remarked that safety was always held as the top priority and that other goals (such as meeting cost and schedule targets)

have lower precedence. Several individuals, however, indicated that all priorities are held equally. They indicated that the culture has changed; where previously any changes were made if safety was tied to it, now risk evaluations are done to assess the level of risk to ensure the change makes sense. In other words, the marginal benefits are weighed against the marginal costs.

The primary barriers to the LCS process given were: lack of buy-in from different Owner groups; resistance to change; liability risk; lack of budget; difficulty in visualizing the site and hazards during design; and a lack of accountability in implementing the suggested changes. The primary enablers of the LCS process were identified as: motivation and input from the Owner (Owner pushing it), additional time available to conduct the reviews, and data available to demonstrate the benefits of the process. No significant changes were made to the different organizations in order to implement the LCS process, except to contract documents that now prescribe participation. The benefits of the LCS process were expected to be: improved safety, better designs, better quality, and more efficient construction.

The interviewees generally felt that LCS could work on any project as long as there was involvement from construction in some form and included in the contract. While the Owner implements the process on every project, the CM implements it or something similar on some of its projects. Those interviewed commented that if the LCS process were to be revised, it should include more ownership of the process on the Owner's side, and more time during the design to conduct the reviews. It should be noted that many of the Owner's projects are done on a fast-track basis, leaving little time to expand design efforts or modify designs.

Microchip Manufacturer Summary Findings from Survey and Interviews

The LCS process provides an effective means for implementing a DfCS process. It involves multiple reviews at different points in the design phase that incorporate the viewpoints of a diverse group of project team members. Trade contractors are a significant part of the process, and special contracting arrangements are created to procure their involvement early in the project lifecycle.

The strong and active involvement of the Owner is recognized and is a significant motivator. It is important, however, that within the Owner firm, accountability and responsibility for the DfCS process be explicitly denoted. The primary motivation is improved safety throughout the lifecycle of the project, and safety is held at a higher priority than other project goals when comparing design alternatives.

In terms of implementing a DfCS process, difficulty in visualizing the design and hazards can be a barrier along with short design durations. When implemented, the process is expected to reduce construction worker injuries and increase quality of construction. There is expected to be an increase in design costs; however, this is likely to be offset by reduced construction costs such that there is no change in overall costs. Similarly, overall durations are not expected to change.

The DfCS process implemented by the Owner is comprehensive and integrated into the Owner's project safety culture. A significant reason for its success is the Owner's intimate involvement in its projects, and its high expectations for safety and health on its projects. This high expectation stems from the Owner's care of its employees and recognition that a safe and healthy workforce is a key aspect to continued efficient production.

Power Generator Findings

Details about the survey and interviews of individuals associated with the power generator case study are provided in Appendix 7.

The Power Generator has developed a DfCS process, which it has titled Design for Safety (DfS), and implemented on all of its large capital improvement projects. The DfS process comprises DfCS checklists, consideration of safety and health in constructability reviews, and in-house design guides and lessons-learned databases focused on DfCS. In addition, focused training on the DfS process is provided to all engineering staff.

Power Generator Survey Data Summary

A total of 12 responses to the survey were received. Demographic information about the respondents was not received as it was an anonymous survey. Appendix 16 contains the MS Excel spreadsheet that summarizes the survey data.

The majority of respondents (58%) had heard of the DfCS concept, while three of the 12 (25%) had not (question 1). It should be noted that the firm's DfCS program covers construction, operations, and maintenance safety, so restricting it to just construction safety may be new to some employees. All of the respondents showed a positive attitude in regards to the DfCS concept (question 2), with 25% indicating that they are willing to try it and 75% stating that they will implement it. When it is implemented, the respondents indicated that checklists, constructability reviews, and in-house design guides are used (question 3).

Comparing DfCS to other safety programs (question 4), almost all of the respondents (83%) felt that DfCS was about the same in terms of importance to preventing injuries. Improving construction worker safety and improving facility occupational safety and health were listed as the top motivators for DfCS. The next most influential motivators were to improve the quality of construction and reducing project cost.

The majority of respondents (67%) felt that AEs would gladly perform DfCS (question 9) and that they would need assistance (42%) or could easily learn the required safety knowledge (42%) (question 10). If it was implemented, 38% of the respondents indicated that any increased design fees could be justified to higher management, and 38% said that there would be no or modest increase in fees (question 12). In terms of liability exposure (question 13), the results were mixed with about half saying that the liability exposure would increase and the other half indicating that it would decrease. The primary reason given for not implementing DfCS (question 14) was it not being applicable to the project (54% of respondents).

The respondents were asked in question 15 to rank the priority of seven different project aspects in terms of their importance to a project, with 1 being the highest priority and 7 being the lowest priority. The combined ranking from highest to lowest priority was as follows: construction worker safety and health (1.64), occupant safety and health (1.82), maintenance worker safety and health (2.00), project cost (4.09), quality (4.18), schedule (4.36), and aesthetics (6.40). Lastly, in terms of impacts to different project outcomes (question 16), the responses were as shown in Table 3 below:

Table 3. Impact of DfCS on Project Outcomes – Power Generator (n = 12)

Outcome	% of Respondents			
	Decrease	No Change	Increase	I don't know
Construction injuries	100%	0%	0%	0%
Design costs	8%	25%	67%	0%
Construction costs	25%	25%	50%	0%
Total costs to owner	33%	17%	42%	8%
Design durations	0%	42%	58%	0%
Construction durations	8%	58%	33%	0%
Total durations	0%	50%	50%	0%
Construction quality	0%	33%	67%	0%
# of lawsuits against owners	58%	17%	17%	8%
# of lawsuits against AEs	58%	17%	17%	8%
Reputation of AEs	0%	25%	67%	8%

Power Generator Interview Summary

Appendix 17 provides a compilation of the answers given during the structured interviews (n = 21 interviews). A summary of this document is provided below.

All interviewees indicated that the driver of the DfS program was upper management within the power company in coordination with the engineering design office. This response is consistent with the history of the program. The motivation for implementing the DfS program, for the firm and for each individual, was to improve safety. It is notable that those interviewed saw the DfS program as a means by which the engineering design office could participate in the firm's overall Target Zero safety program. This tie into the Target Zero program helps the engineering designers feel like they can contribute in some way, rather than safety just being considered as a concern for construction personnel, as is commonly assumed in the construction industry. Responses regarding whether the DfS program would be implemented if the primary driver were not interested in it were mixed. Some indicated that it would have happened through constructability reviews and as a result of its financial benefits. Others indicated that a formal program would not have come about, but it may have been implemented informally.

Initiation of the DfS program came about via an announcement from upper management followed by meetings of the different work groups and development of the checklist. When the program is implemented, opportunities to improve the designs get identified in the review meetings and as part of using the checklist. When a decision needs to be made regarding whether to implement a modified design for safety purposes, the design leads often make the decision on whether it is implemented, however construction leads also provide significant input. Low cost issues are approved right away. Higher cost issues must be approved by the Project Manager. Communication of design ideas and changes is done via e-mail and the DfS database.

The majority of interviewees indicated that conducting DfS reviews are best done earlier in the project to catch hazards before they are "locked in." The disciplines which benefit the most from the reviews (i.e., those disciplines to which the design for safety ideas most apply) include: civil, structural steel (access issues), electrical, and instrumentation and controls (I&C). The power company engineering staff is able to provide a significant amount of input compared to design consultants. The CM and trade contractors were also identified as having a significant amount of input on how to design for safety.

It was clear from those interviewed that safety is the top priority. This is supported not only verbally by the firm, but also when deciding whether to make a change to a design. If a design change will improve safety, it is typically approved regardless of cost. Those interviewed explained that the nature of the facilities and consequences of an accident make safety changes imperative.

Barriers to the DfS program that were mentioned include the need to train the designers about safety hazards, a lack of construction input, and insufficient time to schedule and conduct DfS meetings. A key enabler is good communication between engineering and construction. Also, having safety personnel review the design drawings facilitates identifying hazards. When the DfS program is implemented, the interviewees indicated that outcomes are faster and safer construction, lower cost, designers being more aware of safety implications, and better constructability. The majority of interviewees indicated that they would not change the program if it were to be evaluated for redesign.

Power Generator Summary Findings from Survey and Interviews

The DfS program implemented by the power company is an established program. It is clear that the firm's employees believe in the program and that the firm's upper management has done a good job driving it and motivating the employees. Part of this success has been showing the designers how they can participate in the firm's overall safety goals. The designers feel they are able to contribute and are part of the overall program as opposed to safety just being someone else's problem.

The drive for the program is clearly coming from upper management. Not only has upper management in the firm communicated its desire to implement the program, they have developed supporting resources, a helpful web page for implementation, a training program for all affected employees, and a core DfS Team to oversee it (i.e., to "champion" to use a term from the innovation literature).

As in other case studies, the power generator case study shows it is beneficial to implement design reviews and complete the checklist early in the design phase. The supporting resources (checklist, database, and web page) are very helpful. However, designer training is still needed as well as input from construction personnel. When the program was implemented, there were mixed responses about the impact on overall project cost, some indicating that it would decrease while others feeling that cost would increase. While half said that the project duration would not change, the other half felt that it would increase. More research is needed to monitor a variety of projects to more accurately determine the actual impacts on project cost and schedule.

Energy Company Findings

Details about the survey and interviews of individuals associated with the energy company case study are provided in Appendix 8.

Energy Company Survey Findings

Appendix 18 contains the MS Excel spreadsheet that summarizes the survey data for this case study. This spreadsheet was generated by www.surveymonkey.com, which was used to collect the data. Thirty-four survey responses were received.

For question 2, essentially all of the respondents had positive attitudes about the DfCS concept. That is, almost all of the respondents indicated they would consider having their organization try

DfCS or already have performed it. This response is apparently based either on the brief description of DfCS provided at the start of the survey or on their prior knowledge of the concept. Yet the responses were mixed for question 1 which asked whether their firm has implemented DfCS. Two-thirds of respondents reported they had never heard of DfCS prior to receiving the survey while nearly one-third reported their organization uses DfCS on a limited basis or routinely.

Approximately one-third of the survey participants reported that construction worker safety is part of the A-E scope of work per their contract and over half of the respondents reported that their organization uses design checklists, constructability reviews, and in-house design guides to address construction worker safety and health in the design of its projects (question 3). When asked in question 5 about what motivates or would motivate the respondent to implement DfCS, all of the possible responses except "increase competitive advantage" were checked by at least half of the respondents. When asked in question 15 to rank project priorities, Facility user safety and health (1.90), Construction worker safety quality (2.45) and Maintenance worker safety and health (3.26) were ranked highest by the overall set of respondents out of the eight choices given.

Many of the survey questions addressed potential barriers to DfCS. In general, respondents see few barriers to implementing DfCS. Nearly 80% of respondents indicated for question 9 that AE resistance would not be a barrier because either their organization could insist that the AEs they hire perform DfCS or that the AEs would gladly perform DfCS. Nearly all (93%) respondents indicated it would be easy or unnecessary to modify AE contracts to have them perform DfCS (question 7). Half of the respondents indicated for question 10 that AEs are already capable of performing DfCS or could easily learn enough to perform DfCS while the other half indicated AEs could perform DfCS with assistance from others. When asked in question 11, "If a typical owner was reasonably confident that DfCS would reduce total project costs (design and construction) by 2%, he or she would likely be willing to pay A/Es up to _____% more in design fees to perform DfCS," answers ranged from 0-30%, with the average being 7.7% and a standard deviation of 8.7. With regards to DfCS increasing an organization's liability, 77% reported it would decrease liability while 13% reported it would not change their liability exposure (question 13).

As shown in Table 4 below, when asked to identify how key project results would change if a substantial portion of the industry elected to perform DfCS (question 16), the majority of

Table 4. Impact of DfCS on Project Outcomes – Energy Company (n = 34)

Outcome	% of Respondents			
	Decrease	No Change	Increase	I don't know
Construction injuries	97%	0%	0%	3%
Design costs	7%	14%	76%	3%
Construction costs	38%	24%	31%	7%
Total costs to owner	18%	39%	32%	11%
Design durations	10%	28%	59%	3%
Construction durations	29%	39%	18%	14%
Total durations	7%	48%	26%	19%
Construction quality	4%	29%	68%	0%
# of lawsuits against owners	71%	25%	0%	4%
# of lawsuits against AEs	75%	14%	11%	4%
Reputation of AEs	4%	11%	75%	11%

respondents indicated that construction worker injuries and lawsuits against owners and AEs would decrease while design costs, design duration, construction quality, and the reputation of AEs in society would increase. Opinions on other project results were mixed.

Energy Company Interview Findings

Appendix 19 provides a compilation of the answers given during the structured interviews. A summary of this document is provided below. A total of 10 interviews were conducted.

Safety is given very high priority by top management. Safety is important for business reasons and for public relations reasons, especially after a specific incident tarnished the industry's reputation. The safety of facility users, construction workers, and maintenance workers is always given higher priority over other project goals, including cost and schedule, by decision makers. Interviewees (all of whom were engineers employed by the case study owner organization) are individually motivated to pursue DfCS by a variety of personal values.

The firm does not have an explicit DfCS program but its many established safety planning processes often result in construction safety being considered during design. There were varied opinions about which corporate document requires or encourages DfCS and which department within the organization drives DfCS.

The amount of facility project planning required, the formal required design reviews (which include constructability), and the overall focus on risk analysis and management within the corporation enables DfCS to occur both during formal review events and on an ad hoc basis. The Human Factors Safety Checklist is required at the 30% design review. High risk tasks, such as major crane lifts and other structural phases, receive a particularly high degree of planning effort.

Regarding the respective contributions to DfCS, several respondents stated that the (owner) firm's strong focus on safety and well documented planning and risk management processes contribute significantly to DfCS. Opinions on AE's contributions to DfCS were mixed. Some AE firms have a strong safety culture and program while others do not. GCs and CMs are recognized as being able to make strong contributions to DfCS. They may not have the deep technical expertise that trade contractors do, but their experience with many projects for many clients is valuable for DfCS processes. The role of trade contractors in DfCS processes was not affirmed as critical.

The major barrier to implementing DfCS within the firm would be designers' lack of exposure to the concept and technical ability to perform DfCS. Some respondents voiced that checklists and training to ensure commitment to DfCS would be necessary while others stated that the group was ready to require DfCS now. Several respondents voiced that DfCS would be yet another task added on to an already large set of safety planning requirements and questioned the marginal value DfCS would bring.

Energy Company Findings from Survey and Interviews

Both the interviews and the survey data indicate that safety is the firm's number one priority in all aspects of the firm's operations. This commitment to safety applies to all of the project life cycle, including construction, user operations and maintenance, and always trumps cost, quality and schedule issues. The high value placed on safety and risk management is supported by an established set of required practices, including design reviews that include constructability

analysis and the use of human factors checklists. While the firm does not have a formal or explicit DfCS program, the strong safety culture and set of risk management practices often result in DfCS opportunities being identified and implemented. Respondents see few significant barriers to requiring that DfCS be performed by the outside engineering firms that perform their designs, including the higher design costs that would result from DfCS.

Industry Survey Findings

As summarized in the Research Methods section, members of national construction organizations that include a significant portion of owners were requested to complete essentially the same questionnaire that case study employers completed. A total of 103 completed responses were received. A spreadsheet summarizing the data is provided in Appendix 20. The distribution of responses is as follows:

- Construction Industry Institute (CII): 4
- Owner associations (CURT, AOD, BOMA, and COAA): 6
- Federal agencies (GSA, DOD, DOE): 42
- American Society of Civil Engineers – Construction Institute (ASCE-CI): 2
- Pennsylvania state department of transportation (PennDOT): 38
- Oregon state department of transportation (ODOT): 11

All respondents indicated in question 19 that they worked for an owner organization, not for an AE, design-builder or contractor. (Two of the ASCE-CI respondents left question 19 blank.) Most of the respondents (88%) work for public agencies at the Federal and state level. Approximately 48% of the responses, those from PennDOT and ODOT, come from owner organizations that have construction projects in the infrastructure/heavy civil sector of the industry. The remaining responses (52%) are from owners that have primarily building, laboratory, and industrial facility projects.

Most of the respondents (83%) had not heard about the DfCS concept prior to the survey (question 1). The remainder had either heard about it but do not currently implement it (7%), have been involved in it on a limited basis (8%), or implement it regularly (3%). The respondents' attitude to DfCS (question 2) was overwhelmingly positive as 85% indicated that they either would consider trying it, or have already, or will likely try to implement it. Five of the respondents (5%) indicated that they did not feel the potential benefits of DfCS would be compelling.

The respondents indicated that construction worker safety is addressed in a variety of ways on their projects. Constructability reviews are the primary practice, used by 36% of respondent firms. In-house design guides and design checklists are used by 21% and 15% of the respondents, respectively. It is interesting to note that 12% of the respondents indicated that construction worker safety is already part of the AE's contract. These firms have already made strides to overcome any contractual barriers that might exist to implementing DfCS.

A variety of safety and health programs or processes may be implemented on a project by the owner, designer, and/or contractor. When asked in question 4 how important DfCS is to construction worker safety compared to other safety programs/processes, the most common response was that it is about the same importance (44 of the 103 respondents, 46%). Many of the respondents (35%) indicated that they did not know, 5% felt that it is more or significantly more important, while 13% feel that it is less important or not at all important. Of the 11 respondents

who indicated that their firm implements DfCS either routinely or on a limited basis, nine of the 11 (82%) felt that the importance is about the same.

The respondents' motivation to implement DfCS comes from different sources (question 5). Almost all of the respondents (86%) indicated improved construction worker safety as a motivator. Other sources of significant motivation, and the percent of respondents who identified the source as a motivator, are: improved facility OSH (60%), improved quality of construction (57%), reduced project cost (50%), enhanced reputation (39%), and shorter project schedules (37%). Only 18% of the respondents view competitive advantage as a motivator.

As noted in the review of the existing literature at the beginning of the report, past research has identified potential barriers to implementing DfCS that range from a lack of education to additional liability exposure. One potential barrier is whether typical contract clauses hinder the use of DfCS. Eighteen percent of the respondents indicated for question 7 that it would not be necessary to change their firm's contract language. For those in which changes to the contract clauses are required, 43% indicated that it would be easy and 33% expect that it could be done but would take a lot of work. A minority of the respondents (6%) indicated that their current contracts explicitly reject the idea of AEs having anything to do with safety and that this would not change.

Standard contract documents promulgated by organizations such as AIA and EJCDC are available for use. Eighty-two (80%) of the respondents indicated for question 8 that they are familiar with these types of standard documents. Of those familiar with the documents, 29% indicated that they would support changes to the documents regarding DfCS, 24% would support changes if they do not impact the AE's role and responsibilities, and 21% would support changes if they do not impact the owner's role and responsibilities. Only 7% of the respondents stated that they would not support modifications.

The ability of AEs to design for safety is a possible barrier. The majority of respondents (54%) felt that AEs could implement DfCS with assistance from others who have construction experience (question 10). Forty-two percent of respondents think that AEs could learn how or already have sufficient knowledge to implement DfCS. Regardless of whether AE's are capable or receive assistance, resistance to designing for safety may be a barrier. The respondents' views for question 9 about AE resistance are as follows: 36% feel that some AEs will agree to perform DfCS while others will not; 31% feel that AEs will gladly perform DfCS, and 27% feel that AEs will resist but that their organization can insist that they perform DfCS. Six percent felt that the owners could never insist that AEs perform DfCS.

Implementing DfCS may require additional design services which will increase AE fees for owners. The respondents' perspectives regarding whether potential increases in AE fees are a barrier (question 12) were almost evenly divided among those who feel higher AE fees would become acceptable, those who feel AE fees would not need to increase, and those who feel modest increases would be acceptable (32%). Acceptance of higher fees is also reflected in the 24% of respondents who indicated that increased design fees could be justified to higher management. Eleven percent of the respondents feel that the additional fees would be so much that it would not justify implementing DfCS. When asked in question 11 what percentage increase in design fees would be acceptable if DfCS reduces the overall project cost by 2%, the average percentage increase given by the respondents was 3.2% with a standard deviation of 3.5.

The respondents' views indicate that potential increases in design fees are not seen as a significant barrier.

Additional liability exposure associated with DfCS has often been suggested as a barrier. AEs who implement DfCS have expressed their belief that their liability exposure will increase. With regards to the liability of owner firms, the potential connection to worker injuries, and therefore liability for injuries, is not as clear. When asked in question 13 about how DfCS will affect their organization's liability exposure, most of the respondents (44%) feel that their liability exposure will decrease, 34% feel that it will stay the same, and 21% believe that it will increase. Of the 86 respondents who indicated a positive attitude to DfCS according to question 2 of the survey, thirteen (15%) feel that their liability exposure will increase. The remaining (85%) believe that their liability will remain the same or decrease.

Other barriers suggested by the respondents include the following:

- Difficulty in "selling" the value of DfCS to AE firms and to owner firm upper management, and getting them to change their ways.
- Finding the best circumstances to use this approach and making significant enhancements.
- Not applicable to all projects. On some projects the design is optimized already in terms of construction safety.
- Difficulties in visualizing safety impacts on complicated design drawings.
- Difficulty in incorporating DfCS into the project management process.
- Short design durations.
- Contractors not recognizing and utilizing the design for safety enhancements.
- The typical barriers to making changes within large public organizations.
- Lack of available tools and resources to assist with implementation.
- Current design criteria that places efficiency and durability as higher priorities than safety.

For those firms that considered implementing DfCS but decided against it (73 firms), the primary reasons for not implementing it (question 14), along with the percentage of respondents who selected that reason, were: not enough information/knowledge of DfCS (40%), too costly (33%), added design duration (33%), no perceived benefit (18%), and other project objectives have a higher priority (14%). The overall response to this question gives additional evidence of the practical issues that create obstacles for implementation of DfCS. When specifically asked in question 15 about priorities, construction worker safety is ranked highly, but not as high as cost and occupant safety and health. Figure 5 shows the average rankings of different project criteria in terms of their priority on a project (1 = highest priority, 2 = second highest priority, and so forth). A lower number indicates a higher priority.

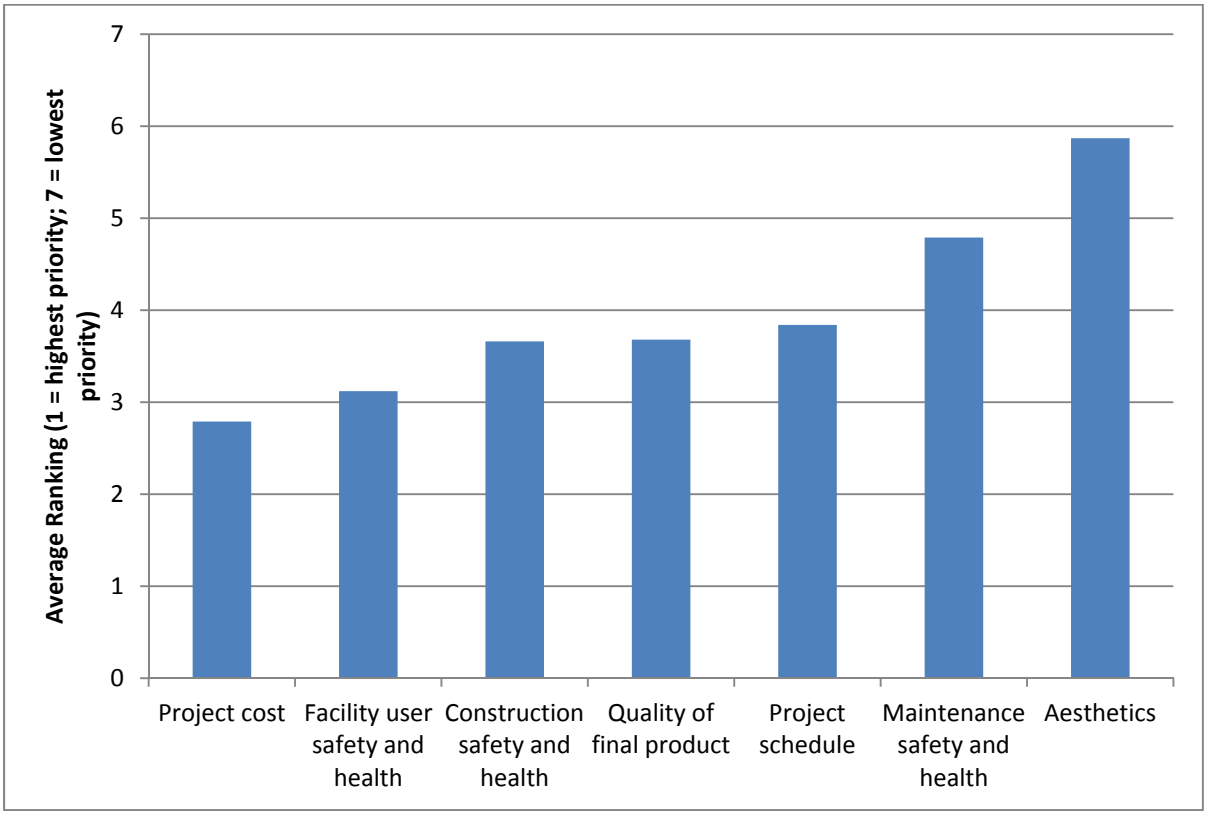

Figure 5. Ranking of Project Criteria (n = 103)

Implementing DfCS is expected to impact various project outcomes and organizational characteristics. The respondents were asked to indicate what they felt would be the impact to a set of project outcomes (question 16). A summary of the responses is provided in Table 5. Most of the respondents (81%) foresee a decrease in construction worker injuries. The majority of respondents (59%) feel that total project costs and total project durations would increase. A significant proportion (30%) indicated an increase in construction quality. While previous survey questions indicated liability to be a concern, most feel that the number of lawsuits against owners and against AEs would decrease. The majority of respondents (45%) also feel that the reputation of AEs would improve.

Table 5. Impact of DfCS on Project Outcomes – Industry Survey (% of Respondents, n = 103)

Outcome	% of Respondents			
	Decrease	No Change	Increase	I don't know
Construction injuries	81%	9%	2%	8%
Design costs	2%	11%	77%	10%
Construction costs	15%	28%	48%	9%
Total costs to owner	11%	20%	59%	10%
Design durations	1%	23%	67%	9%
Construction durations	12%	43%	35%	10%
Total durations	6%	26%	59%	9%
Construction quality	1%	55%	30%	14%
# of lawsuits against owners	42%	22%	12%	24%
# of lawsuits against AEs	30%	21%	24%	25%
Reputation of AEs	3%	32%	45%	20%

Key Industry Survey Findings

The industry survey provided an opportunity to determine and analyze the construction industry's experience with, and perspectives of, the DfCS concept. The DfCS concept is still a relatively new concept as most respondents had not heard about it. However, interest in the concept is strong and most have a positive attitude towards it. If they were to implement it, incorporating it into the constructability review process would be a logical place to start as many of the firms utilize constructability reviews on their projects. Other tools on which it could be included, and which are currently utilized, are in-house design guides and design checklists.

The respondents believe that the importance of DfCS is relatively the same as other safety and health programs/processes. Motivation to implement DfCS would come primarily from fewer construction injuries, improved facility OSH, improved quality of construction, and reduced project cost. This is promising as the respondents believe that not only will the number of construction injuries decrease as a result of implementing DfCS, but construction quality will either stay the same or increase.

To add DfCS to the list of implemented programs/processes, it is important that DfCS is seen as a valued contributor to construction safety and health when compared to other safety and health programs/processes. The DfCS process is perceived to have about the same importance as other programs/processes. Both safety research and traditional OSH education indicate that DfCS would be the best means of improving construction worker safety as it is at the top of the hierarchy of controls.

As with previous research, owner organizations see barriers to implementing the DfCS process. These barriers include: a lack of knowledge about DfCS, potential increased liability, project cost, and project duration, AE education and stance towards change, difficulties in visualizing safety and health hazards, and others. The list of barriers is similar to that identified for AE firms in previous research. Some firms throughout the industry regularly implement DfCS and see benefits, therefore, the identified barriers are not insurmountable. The continued benefits associated with implementing DfCS outweigh the costs. Additional AE fees as a result of implementing DfCS were not felt to be a significant barrier.

Analysis of the Findings related to the Research Objectives

This section of the report synthesizes the findings from the case studies and the industry survey in an attempt to answer the seven research objectives identified at the beginning of the report. The previous Findings section summarized the survey and interview data from each case study and for all industry surveys. The tables in this section provide a quantitative summary and comparison of the survey findings from all case studies combined, from the industry survey, and from the combination of case study and industry surveys.

Research Limitations

Before reviewing the overall findings from the research, it is appropriate to first note the methodological shortcomings because they influence the confidence in the apparent findings. It is also appropriate to remind the reader that the research was intended to be exploratory (not confirmatory) research on an emerging topic that has not been extensively researched.

The research methodology implemented was a combination of a very small (four) sample of case studies and a survey of over 100 industry professionals not associated with the case study firms.

The small case study sample means that there is a significant chance that the firms are not representative of the rest of the industry. The fact that the four firms were chosen based on past interactions with the researchers rather than randomly chosen further increases the chance of bias. An additional source of bias is that not all of the case study employees invited to be interviewed or to complete a survey chose to do so, i.e., the results are subject to selection bias due to the volunteerism on the part of the participants. The fact that some interviewees were not asked all of the interview questions due to time constraints limits the generizability of the findings. A final research concern is that the researchers do not know how many of the questionnaires were completed by individuals who were interviewed (i.e., there may be some overlap between case study interviewees and case study survey respondents). It should be mentioned that in two of the surveys of individuals associated with the case studies, the surveys were not completed only by owner employees. Specifically, three out the seven microchip manufacturer surveys were employees of contractors, not of the microchip manufacturer, and twenty-four out of the twenty-six hospital project participants were with design and/or construction firm employees.

The primary methodological flaw associated with the industry survey (the risk of self-selection bias) is common to the case study survey. Individuals who decided to participate may have different opinions on DfCS than do individuals who chose not to participate in the survey. In other words, the volunteer nature of the survey means that the participants are not representative of the overall industry. The likelihood of such a bias is impossible to estimate because the number of individuals who received the invitation but elected not to complete the questionnaire is not known.

Research Objective 1: To identify the approximate percentage of owners who are already aware of the design for construction safety concept.

Table 6 below shows that the vast majority of industry survey participants had not heard of DfCS prior to taking the survey. The percentage of case study respondents was smaller but still over 50%. Note that the case study survey data are not helpful for addressing this objective because 29% of the combined case study survey respondents were employees of a non-owner company (such as AE or contractor). Also, the case study sample is clearly not representative of the overall industry because it intentionally included two organizations that were known to have implemented DfCS. As mentioned above, the fact that the industry survey was completed by

Table 6: Findings from Survey Question 1

1. Had you heard of Design for Construction Safety (DfCS) before this survey?	Industry Surveys (n = 103)	Case Study Surveys (n = 79)	All Surveys (n = 182)
I had never heard of DfCS.	**83%**	56%	71%
I had heard of DfCS but my organization has never considered implementing it.	7%	6%	7%
My organization has considered implementing DfCS but has never done so.	0%	3%	1%
My organization has been involved with DfCS on a limited basis.	8%	11%	9%
My organization routinely ensures DfCS occurs on our projects.	3%	24%	12%

volunteers raises the possibility that the survey was biased; however, it would seem that individuals who received the survey request and had heard of the DfCS concept would be more likely to choose to take the survey than would those who had never heard of DfCS. It is therefore likely that the actual percentage of employees of owner organizations that have not heard of DfCS would be higher than the numbers shown in Table 6 and the percentages that have been involved with DfCS would be lower.

It is interesting to note that while 83% of industry respondents indicated they had never heard of DfCS, the responses to question 3 suggest that respondents' organizations are essentially performing DfCS (i.e., considering construction worker safety in project design) even if they do not call it DfCS. Specifically, as shown in Table 7, 36% indicated that constructability reviews were used to consider construction worker safety during design and only 14% who responded indicated that their organization had no processes or resources for having construction worker safety considered in project design. Table 7 also shows that constructability reviews were the most common tool or process associated with DfCS for the case study firms.

Table 7: Findings from Survey Question 3

3. If your organization formally addresses construction worker safety and health in the design of its projects, what process/resources does it use? Please check all that apply.	Industry Surveys (n = 103)	Case Study Surveys (n = 79)	All Surveys (n = 182)
Construction worker safety is part of the architect-engineer (A/E) scope of work per their contract	12%	13%	13%
Design checklists	15%	24%	20%
Constructability reviews	**36%**	31%	33%
In-house design guides	21%	23%	22%
Computer program	2%	6%	4%
Other	0%	0%	0%
No specific process/resources	**14%**	4%	9%

Research Objective 2: To identify how owners who are or become aware of the DfCS concept feel about how promising DfCS is as an intervention for improving construction worker safety and health. That is, to identify the percentage of owners who perceive the DfCS concept to be an important process for reducing construction injuries and improving the health of construction workers.

Three questions on the survey are relevant to this research objective: Questions 2, 4 and 16. Question 2 is most directly related because it asks for the respondent's overall attitude towards DfCS. As shown in Table 8, both the industry survey and the case study data indicate that DfCS is a promising concept among the industry practitioners surveyed. The sum of the two answer categories "The benefits of DfCS sound like a good idea. I would consider trying it" and "DfCS sounds like a winner. I have already or will likely try to implement it" was 85% (68%+17%) for the industry survey and 94% (46%+48%) for the case study survey. Only 5% and 4%, respectively, agreed with the statement "The potential benefits of DfCS do not seem compelling to me."

Table 8: Findings from Survey Question 2

2. Which statement best matches your overall attitude toward the DfCS concept?	Industry Surveys (n = 103)	Case Study Surveys (n = 79)	All Surveys (n = 182)
The potential benefits of DfCS do not seem compelling to me.	5%	4%	4%
The benefits of DfCS sound promising but there are too many barriers to try implementing it.	11%	3%	7%
The benefits of DfCS sound like a good idea. I would consider trying it.	**68%**	**46%**	58%
DfCS sounds like a winner. I have already or will likely try to implement it.	**17%**	**48%**	30%

Question 16 data also provide insights into owners' attitudes towards DfCS in that it asks them to predict the consequences if DfCS became more widely diffused in the construction industry. With regards to desirable outcomes, Table 9 shows that 81% of industry survey respondents predict that the adoption of DfCS will decrease construction injuries, and 42% predict DfCS will decrease the number of lawsuits against owners. The values for the case study respondents were 96% and 73%, respectively. Also note that Table 9 shows that 65% of case study survey respondents predict DfCS will decrease lawsuits against AEs and Table 10 (next page) shows 70% expect it will increase construction quality. With regards to undesirable outcomes, Table 10 shows that the majority of industry respondents predict that the diffusion of DfCS will increase design costs and design durations.

Table 9: Findings from Survey Question 16 for DECREASES*

16. If a substantial portion of the industry elected to perform DfCS on projects, how *might* the following items change?	Industry Surveys (n = 103)	Case Study Surveys (n = 79)	All Surveys (n = 182)
Construction injuries	**81%**	**96%**	87%
Design costs	2%	4%	3%
Construction costs	**15%**	**38%**	24%
Total project costs to the owner	**11%**	**27%**	18%
Design durations	1%	4%	2%
Construction durations	**12%**	**30%**	19%
Total design and construction durations	6%	16%	10%
Construction quality	1%	6%	3%
The number of lawsuits against owners	**42%**	**73%**	55%
The number of lawsuits against A/Es	**30%**	**65%**	45%
The reputation of A/Es within society	3%	3%	3%

* For example, this table shows that 81% of industry survey respondents answered that "If a substantial portion of the industry elected to perform DfCS on projects" construction injuries would decrease.

Table 10: Findings from Survey Question 16 for INCREASES

16. If a substantial portion of the industry elected to perform DfCS on projects, how *might* the following items change?	Industry Surveys (n = 103)	Case Study Surveys (n = 79)	All Surveys (n = 182)
Construction injuries	2%	0%	1%
Design costs	**77%**	**68%**	73%
Construction costs	48%	32%	41%
Total project costs to the owner	**59%**	**32%**	48%
Design durations	**67%**	**55%**	62%
Construction durations	35%	15%	27%
Total design and construction durations	**59%**	**31%**	48%
Construction quality	**30%**	**70%**	47%
The number of lawsuits against owners	12%	3%	8%
The number of lawsuits against A/Es	**24%**	**11%**	19%
The reputation of A/Es within society	**45%**	**68%**	54%

The data for question 4 are also relevant to this research question as it asks about DfCS' relative importance for maximizing safety and health on the jobsite. It is possible that respondents could think positively about the DfCS concept (question 2) but feel it is or would not make an important contribution to safety. Similarly, it is possible that respondents could think that DfCS would decrease construction injuries (the first cell in question 16) but feel that the decrease would be incremental and insignificant. Yet, as shown in Table 11, nearly half of both the industry and case study survey respondents indicated DfCS could have the same importance as other safety management elements (i.e., hazard analysis, safety inspections and the use of personal protective equipment during construction).

Table 11: Findings from Survey Question 4

4. If your organization implements DfCS on projects, how important is DfCS to construction worker safety and health compared to other safety and health programs/processes that are currently implemented? DfCS is:	Industry Surveys (n = 103)	Case Study Surveys (n = 79)	All Surveys (n = 182)
Not at all important	3%	0%	2%
Less important	10%	4%	8%
About the same importance	46%	48%	47%
More important	3%	14%	8%
Significantly more important	2%	7%	4%
I don't know	35%	27%	32%

Research Objective 3: To identify the extent to which owners feel they can insist that the architect/engineers (AEs) they contract with for design services perform DfCS on their projects.

Survey questions 7 and 9 are relevant to this research question. The data for question 9, which is most directly related to the objective, are summarized in Table 12 below. The data show that the vast majority of both industry and case study survey participants agree that AE resistance is non-trivial (the percentages of respondents who indicated AE resistance would NOT be an issue was only 31% for the industry survey and 43% for the case study surveys) but not insurmountable

(the percentages who indicated AEs could not be forced to perform DfCS was only 6% for each survey group).

Table 12: Findings from Survey Question 9

9. Please place a check by the statement that best reflects how you feel about potential A/E resistance as a barrier to DfCS.	Industry Surveys (n = 103)	Case Study Surveys (n = 79)	All Surveys (n = 182)
A/Es will never agree to perform DfCS and my organization cannot force them to do it.	6%	6%	6%
A/Es will resist, but my organization can insist the A/Es we hire perform DfCS.	27%	18%	23%
Some A/Es my organization uses will agree to perform DfCS while others will not.	36%	33%	35%
Most of the A/Es my organization uses will gladly perform DfCS.	31%	43%	36%

It is interesting to note that the higher percentage of respondents indicating "Most of the A/Es my organization uses will gladly perform DfCS" cannot be explained merely by the fact that two of the case study firms had a formal DfCS program (which likely requires AEs to perform DfCS). As noted in the discussion of the survey data for the energy company earlier in this report, the energy company does not have a formal DfCS, yet 52% of the 34 respondents agreed that AEs will gladly perform DfCS. The authors believe the data pertaining to this question likely reflect the market segment of the respondent. AE resistance in the commercial building market would be expected to be much higher than in industrial/process construction for three reasons. First, the preponderance of traditional design-bid-build project delivery in commercial construction means there is more fragmentation (i.e., less integration or collaboration) between design and construction . Second, the commercial market is much less focused on safety than are the process and infrastructure markets. Third, owners in commercial construction are much less involved in design and construction processes than are owners in the process and infrastructure markets.

Question 7 is also relevant to AE resistance in that the model contracts promulgated by the American Institute of Architects and the Engineers Joint Contracts Document Committee (which is composed of the American Society of Civil Engineers, the American Council of Engineering Companies and the Associated General Contractors) include paragraphs that explicitly state that the designer has no involvement in or association with construction site safety at all. Many industry practitioners therefore assume that their company's typical contractual language explicitly prevents them from performing DfCS. (The authors believe that underlying the DfCS concept is the assumption that designers will be involved in safety analysis during the design stage but will have NO responsibility for site safety during construction.) The data for question 7 (summarized in Table 13) are similar to that for question 9 in that the vast majority in each group feels that the barrier to performing DfCS associated with typical contract clauses is not substantial and that only a small percentage of respondents feel that contract language will be an insurmountable barrier.

Table 13: Findings from Survey Question 7

7. Please place a check by the statement that best reflects how you feel about whether typical contract clauses hinder the use of DfCS.	Industry Surveys (n = 103)	Case Study Surveys (n = 79)	All Surveys (n = 182)
The language in my company's typical design and construction contracts explicitly rejects the idea of A/Es having anything to do with safety and this won't change.	6%	8%	7%
It would take a lot of work, but the typical language in my company's contracts that conflicts with A/Es performing DfCS could be changed.	33%	10%	24%
It would be easy to modify my company's typical contract language to allow A/Es to perform DfCS.	43%	46%	44%
It would not be necessary to change my company's typical contract language to allow an A/E to perform DfCS.	18%	37%	25%

Research Objective 4: To identify the perceived and actual barriers that might prevent owners from implementing DfCS on their projects.

Research Objective 3 addressed above is associated with the specific potential barriers to DFCS of AE resistance and model contract terms. As discussed in the literature review section, additional potential barriers include: AEs not being capable of performing DfCS, AEs needing to increase their fees too much to perform DfCS, Owners perceiving that having DfCS performed on their projects will increase their own liability , and various organizational barriers. Findings from the data for these potential barriers will be discussed one at a time.

<u>AEs not being capable of performing DfCS:</u>
The data for survey question 10 in Table 14 shows that AE capability to perform DfCS is not expected to be a problem. Only 3% of the combined industry and case study survey respondents believe that AEs could never learn enough to perform DfCS. Ninety-seven percent, the remaining respondends, stated that AEs could be, or are now, capable with assistance or without assistance.

Table 14: Findings from Survey Question 10

10. Please place a check by the statement that best reflects how you feel about whether A/Es are capable of performing DfCS.	Industry Surveys (n = 103)	Case Study Surveys (n = 79)	All Surveys (n = 182)
Most A/Es could never learn enough to effectively perform DfCS.	4%	1%	3%
It would take a lot of effort, but most A/Es could learn enough to effectively perform DfCS.	25%	8%	18%
Most A/Es could perform DfCS with assistance from others, e.g., Construction Managers and contractors.	54%	53%	54%
Most A/Es could easily learn enough to effectively perform DfCS.	12%	25%	17%
Most A/Es are already capable of effectively performing DfCS.	5%	12%	8%

AEs needing to increase their fees too much to perform DfCS:
The data for question 12 shown in Table 15 indicate that increased AE fees due to DfCS being implemented are not expected to be a problem. Only 8% of total survey respondents indicate higher AE fees will prevent DfCS from being adopted within the industry. Ninety-two percent of the sample indicates AE fees would not increase more than modestly and/or could become acceptable. The data related to research objective 5 and survey question 11, which also relate to AE fees increasing due to DfCS, will be discussed shortly.

Table 15: Findings from Survey Question 12

12. Please place a check by the statement that best reflects how you feel about whether potential increases in A/E fees are a barrier to DfCS in the industry.	Industry Surveys (n = 103)	Case Study Surveys (n = 79)	All Surveys (n = 182)
A/Es would need to increase their fees so much to perform DfCS that it will never happen.	11%	3%	8%
It would take a lot of work, but the higher design fees associated with A/Es performing DfCS could become acceptable.	32%	19%	27%
The increased design fees associated with DfCS could be justified to higher management.	24%	46%	33%
A/Es would not need to increase their fees and/or the modest increases would not be a problem at all.	32%	32%	32%

Owners feeling that having DfCS performed on their projects will increase their own liability:
The data for survey question 13 indicate the respondents hold mixed opinions on whether DfCS will increase the liability for the owner. As shown in Table 16, approximately one-fifth of each survey group indicated that DfCS would increase their own firm's liability exposure. While 70% of the case study respondents indicated they would expect DfCS to decrease their firm's liability exposure, only 44% of industry survey participants felt the same way. Question 16 also had relevant data. As shown in Tables 9 and 10, the percentage of industry survey respondents who indicated DfCS would decrease the number of lawsuits against owners was 42% while the percentage who indicated DfCS would increase the number of lawsuits was 12%. The corresponding numbers for case study respondents were 73% and 3%, respectively.

Table 16: Findings from Survey Question 13

13. Please place a check by the statement that best reflects your concerns about your organization's liability with respect to DfCS.	Industry Surveys (n = 103)	Case Study Surveys (n = 79)	All Surveys (n = 182)
I believe that addressing construction worker safety during design is likely to increase my organization's liability exposure.	21%	19%	20%
I believe that whether or not construction worker safety is addressed during design will not affect my organization's liability exposure.	34%	12%	25%
I believe that addressing construction worker safety during design is likely to decrease my organization's liability exposure.	44%	70%	55%

Various organizational barriers[1]:

Data from question 15 indicate the relative priorities that the participant's organization puts on various project goals. These data are relevant to the issue of barriers because low priority on safety would serve as a barrier to the adoption of DfCS. As shown in Table 17, the average priority given for construction workers safety and health by industry survey respondents was 3.66 (out of 7 choices), behind project cost (mean=2.79) and facility user safety & health (mean= 3.12), and slightly ahead of project schedule and project quality. For the case study data, construction worker safety averaged the second highest priority (mean = 2.66), just behind facility user safety and health (mean 2.64). The next closest items had a considerably higher average rankings, i.e., were given considerably less priority on average. These data therefore indicate that construction worker safety and health is given sufficient priority that competing project and organizational priorities should not serve as a barrier to DfCS. It should be noted, however, that research effects may be present, that is, the relatively high ranking indicated for construction worker safety may reflect in part the fact that the participants knew the survey was being performed by researchers interested in construction safety.

Table 17: Findings from Survey Question 15

	Aesthetics	**Const. worker safety & health**	Facility user safety & health	Maint. worker safety & health	Project cost	Project schedule	Quality of final product
Industry Mean	5.87	3.66	3.12	4.79	2.79	3.84	3.68
Industry Median	7.00	3.00	3.00	5.00	2.00	4.00	4.00
Industry Std. Dev.	1.68	2.19	1.70	1.70	1.63	1.64	1.70
Case study Mean	6.13	2.66	2.64	3.59	3.82	4.18	3.81
Case study Median	7.00	2.00	2.00	3.00	4.00	4.00	4.00
Case study Std. Dev.	1.58	1.96	1.81	1.90	1.59	1.41	1.78

Research Objective 5: To identify the range of premiums, either in designer fees or construction cost, that owners will accept for implementing DfCS.

The researchers found that creating a survey question to directly address this research objective was more challenging than anticipated. It was assumed that most practitioners would frame the question in terms of payback or rate or return, yet because most survey respondents would be unfamiliar with the potential benefits of DfCS (including financial and improved safety), it seemed necessary to anchor the question with a specific financial savings. Consequently, the survey included a question (number 11) with the following wording: "If I was reasonably confident that DfCS would reduce my total **project** costs (design and construction) by 2%, I would be willing to pay A/Es up to _____% more in **design** fees to perform DfCS."

[1] Note: Question 14 was thought by the researchers to be relevant to the issues of barriers because the question is directly related to why the survey participant has heard of DfCS but it has not been implemented. After the data were collected, however, the researchers realized the question was ambiguous in that the first answer, "Not applicable to my organization," could have been checked by respondents who felt that DfCS is not applicable to their organization as well as by respondents who felt that their organization has already implemented DfCS so the question is not applicable.

This wording was apparently not wholly effective as only 31% of the case study survey respondents and only 83% of the industry survey respondents answered the question. The industry survey data ranged from 0-20% and had a mean of 3.17, a median of 2.00 and a standard deviation of 3.46.

Research Objective 6: To identify how owners' opinions and acceptance of DfCS vary with organizational characteristics.

Unfortunately, it was not possible to gain insights into this research question using the data collected in this study. The case study survey data would not be appropriate to analyze for this question since the sample includes only four case studies, including two that had twelve or less participants and two that had essentially identical demographics for all survey participants. Also relevant is fact that only one case study was associated with the commercial building market segment while three case study firms are associated with the process/industrial market segment. While the size of the industry survey sample (N=103) would normally be sufficient to perform cross-tabs or ANOVA, the cell counts of certain participant characteristics were not sufficient to yield meaningful results. The time and effort required to obtain just 103 completed surveys was much more than the researchers anticipated and time limitations prevented achieving a larger sample size.

Research Objective 7: To create the documents needed to facilitate the adoption of DfCS by owners.

Research objective 7 is not related to survey data questions per se, but the results of the surveys (or case studies) underscore the importance of creating such documents. The next section addresses these documents.

Recommendations and Conclusions

This section of the report provides recommendations and conclusions based on the literature reviewed, the survey and interview data, the various DfCS-related documents obtained from the four case studies, and the authors' background knowledge and experiences with DfCS gained prior to, during, and after the data collection stage of this research. As was the case for the research findings presented in the last section, these recommendations are organized by the planned research objectives. Given the previously identified limitations and deficiencies associated with this exploratory research project, these recommendations and conclusions should be regarded as preliminary.

Research Objective 1

The industry survey shows that the vast majority of the design industry has not heard of DfCS. Awareness of an innovation is always the first step in the adoption process of an innovation (Rogers 2003), so individual owners who wish to have DfCS occur on their projects should establish a formal DfCS program that includes making all employees aware of the DfCS concept. Government agencies and professional associations that wish to promote the diffusion of DfCS should develop formal initiatives to increase awareness of the DfCS concept among potential adopting organizations. For example, OSHA and/or NIOSH could develop a "marketing" campaign that includes presentations at professional conferences, an owner-oriented page on a website, and informational postings on online owner safety communities, such as Linked In.

Research Objective 2

The industry survey data show that when owner employees read even a simple description of the DfCS concept, the response of a strong majority is highly positive. Specifically, a high percentage of survey participants indicated an interest in implementing DfCS within their organizations and a perception that if DfCS is widely adopted within the construction industry, construction injuries would decrease. Other survey results that bode well for DfCS include that over one-half of combined survey participants anticipate that diffusion of DfCS would increase the reputation of AEs within society while less than one-fifth expect that the number of lawsuits against AEs would increase.

The data related to Research Objective (RO) 2 confirm the recommendations for RO1: individual organizations, trade associations, and government agencies interested in promoting DfCS should implement programs to increase awareness of the DfCS concept. If the findings related to R01 are considered as bad news (in that most of sample had not heard of DfCS), the findings related to R02 are good news in that even a quick, high level exposure to DfCS leads to a positive attitude towards it. In short, the DfCS concept is easy to communicate, intuitive, and compelling. Communication of the DfCS benefit should include not only the direct benefit of reduced construction injuries, but also the expected indirect benefit of increasing AEs' reputations within society.

Research Objectives 3-5

The third through fifth research objectives pertained to the perceptions of barriers to DfCS being adopted within a firm or diffused in the industry. RO3 focused specifically on whether AE resistance will serve as a barrier to DfCS. The data indicate that very few respondents predict that AEs will refuse to perform DfCS, which suggests that this potential barrier need not be addressed when making potential adopters aware of the DfCS concept.

The implications of the data related to whether DfCS will increase the liability exposure to either owners or AEs are similar to the previous paragraph. With approximately one-fifth of the industry survey respondents predicting that DfCS would increase their organization's liability, the percentages of both industry and case study respondents who predicted DfCS would decrease AE liability were greater than those who predicted DfCS would increase AE liability. As such, it appears that it is not necessary to address liability concerns when communicating the DfCS concept to owners.

The data also suggest that AE ability to perform DfCS should not ultimately serve as a barrier to implementing DfCS but that AEs will require training on DfCS with assistance from construction field personnel. As such, efforts to promote DfCS should not only make potential adopters aware of the DfCS concept, but also communicate the training and collaboration likely needed to have DfCS performed successfully.

The findings relating to AE design fee increases associated with DfCS are similar to those just mentioned: Increased design fees are not ultimately expected to serve as a barrier, but design fees are expected to increase and organizational effort will be required to justify the fee increases to management and make them acceptable. Whether it would be appropriate to address increased design fees when making owners aware of the DfCS concept is not clear from the research.

Research Objective 7

The following paragraphs provide a brief guide for owners on key factors in implementing DfCS on their projects.

Strong Leadership and Safety Culture. It is generally accepted that the culture within an organization significantly influences the behavior of individual employees and that leadership plays a central role in establishing an appropriate organizational culture. With regards to DfCS, leadership is required on the owner's part to set a high expectation for worker safety and health, to ensure that safety takes priority over other project criteria to ensure that when multiple options are available to mitigate a hazard, designing out the hazard is desired and chosen whenever practicable.

Business Value of DfCS Recognized Through a Total Project Cost Perspective. Although it was noted earlier in the report that some DfCS researchers and safety practitioners believe that DfCS should be performed because it is the ethical thing to do, the implementation of DfCS will be more effective if DfCS is viewed by managers and employees as being the smart thing to do because it makes financial sense. Given that DfCS will likely at least initially increase design fees, it is important that DfCS be viewed using a total project, life cycle cost perspective, that is, by identifying all of the costs and benefits associated with DfCS over the life cycle of the constructed facility, not just the costs associated with the design phase or just the construction phase. Managers must recognize that while design costs will likely be higher for projects on which DfCS is implemented, the total project costs will be lower because the resulting design will yield lower workers compensation insurance costs and fewer delays due to injuries. Construction productivity should be higher and construction duration should be shorter because workers will not have to use PPE and other means to manage exposure to risks that have been designed out. Furthermore, maintenance costs over the life of the facility should be lower because the DfCS process should also reduce hazards that maintenance workers will be exposed to. Although the indirect benefits listed above have not yet been documented through research, the authors believe the repeated implementation of DfCS will eventually allow research to be performed that will document these benefits.

Formal DfCS Program. An explicit DfCS program is required for both symbolic and practical reasons. A formal DfCS program is needed to inform employees of the DfCS concept, provide an objective and efficient process for its implementation, ensure that needed collaboration occurs, and provide a structured means for monitoring and enforcing the program. Construction projects always have competing priorities and cost/budget and time/completion date typically are either explicitly or implicitly identified as the top priorities, followed closely by construction quality. Without a formal DfCS program, a desire and/or agreement to perform DfCS is likely to be overwhelmed by competing priorities.

DfCS Explicitly a Factor in AE Selection. Proactive owner involvement is likely necessary to initiate implementation on a project. Without a regulatory requirement, recognized duty, or immediate financial incentive, some AEs (especially in the commercial construction market segment in which construction safety is typically not given a high priority among project goals) will be reluctant to take on the role and responsibility of designing for construction safety. Owners must ensure AEs are willing and able to perform DfCS through the AE selection process. Ideally, owners should contract with AEs who have a formal DfCS program themselves and a demonstrated track record of performing DfCS. At the least, AEs should be required to submit documentation that they understand the DfCS concept and are willing to have their

designers undergo training on how to perform DfCS, to use DfCS tools, and to collaborate with owner and contractor personnel during design to effectively perform DfCS.

DfCS Processes: Processes to ensure frequent and effective interaction between the owner, designer, and contractor must be established at the start of design. Initial training to ensure that everyone understands the value and principles of the DfCS process will likely be required. Informal teambuilding exercises will help establish needed trust. Processes must be established for tracking and fully investigating each DfCS suggestion, whether the suggestion is initiated during a formal design-constructor meeting, during an informal conversation, or while one party is reviewing design documents online. After the project is completed, the results of DfCS decisions should be analyzed and incorporated into a corporate Lessons Learned database to allow future projects to benefit from the project participants' DfCS experiences.

Project Delivery Method. The literature and interviews indicate that—even if designers are knowledgeable about construction safety and DfCS—collaboration during design between designers, the lead contractor, construction trades, and construction safety professionals is a key component of an effective DfCS program. The traditional design-bid-build method of delivering projects typically does not allow this collaboration because the firms who perform construction are not identified until after design is complete. As such, design-build and integrated project delivery (IPD) are two preferred project delivery methods for enabling effective DfCS on a project because they enable the needed collaboration.

Design Contract Type: Owners who wish to engage an AE who has not previously performed DfCS may wish to agree to have the contract with the AE be a Cost-Plus with a guaranteed maximum price (GMP) contract rather than a traditional fixed price contract, because such a designer is likely to be hesitant about locking in a price for a process with which they are not familiar. The DfCS process will be unfamiliar to them in two ways. First, they will not know how much time their design staff will require to consider construction safety while making design decisions. Second, they will not know how much time it will require to incorporate input from contractors into the design, some of which will be directly related to safety while others will not be safety related but still come up during discussion.

Contractual Obligations. Although it is more difficult to effectively perform DfCS on a traditional design-bid-build project, it is not impossible. An owner could choose to require the AE to perform DfCS without being able to collaborate with construction personnel during design, or an owner could engage a general contractor and several key trade contractors to act as safety review consultants during the design process. With either arrangement, it will be necessary to ensure the contract between the owner and the AE requires or at least recognizes that the AE will perform DfCS on the project. Appendices 21 and 22 include suggested changes to two model contract documents promulgated by the Engineers Joint Contracts Committee (EJCDC, a joint body of the American Society of Civil Engineers, the National Society of Professional Engineers and the Associated General Contractors.). The E-500 is a model contract (i.e., boiler plate) contract between and owner and design engineering on a design-bid-build project. The E-700 is model general conditions that govern a general contractor and subcontractors on a design-bid-build project. (The documents are analogous to the B-141 and the A201, respectively, promulgated by the American Institute of Architects.)

Constructability Reviews. The key collaboration with DfCS is associated with constructability reviews, that is, when designers and construction personnel meet to discuss aspects of the design

that may cause the construction of the design to cost more, take longer, or be of lower quality than is desired. Ideally, such constructability reviews occur at approximately the 10%, 30%, 60% and 90% stages of design, involve individuals representing all relevant engineering disciplines, in-house construction safety, external trades, operational safety, and cost accounting, and include the specific review tasks shown in Figure 6 below.

A mistake that is common on construction projects is not to hold the first constructability review until later in the design process. As suggested in Figure 6, opportunities for identifying and facilitating prefabrication and modularization disappear around the 30% design stage. Because prefabrication and modularization can dramatically reduce construction injuries over "stick-built" construction (Toole and Gambatese 2009), constructability reviews that do not start until after the 30% design stage have significantly lower potential for designing a facility that is inherently safer to construct.

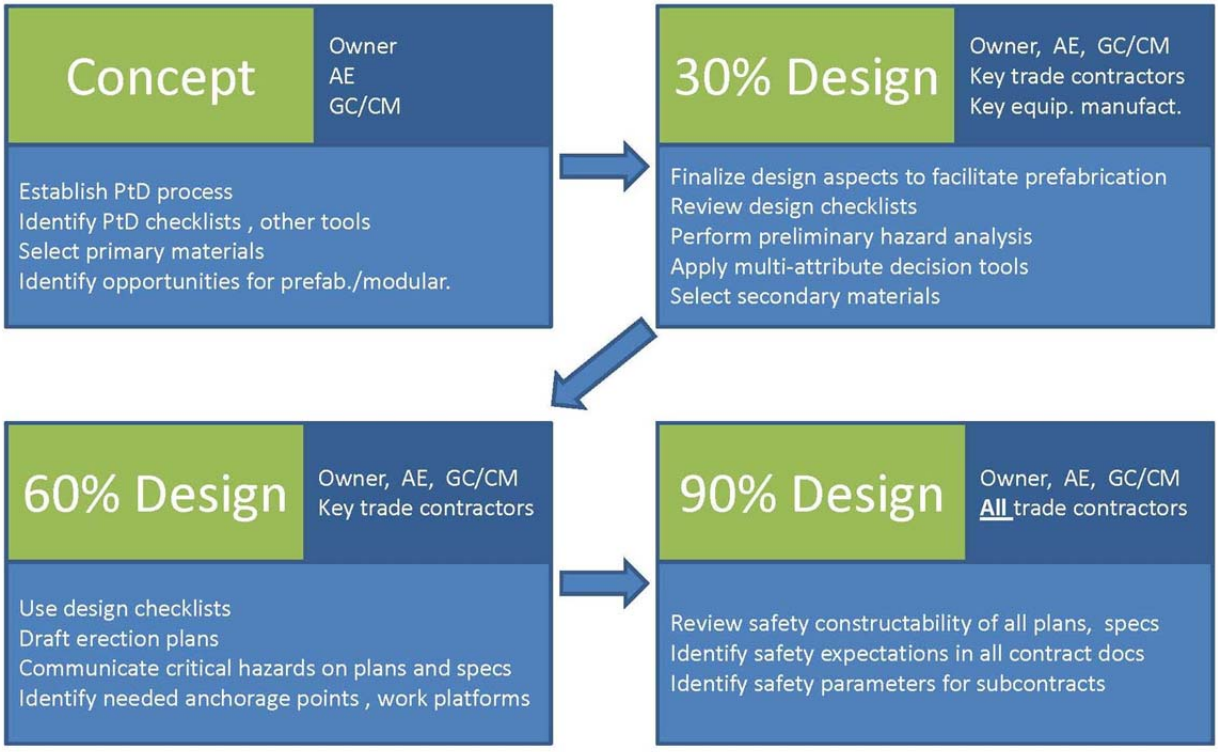

Figure 6: The Ideal Constructability Review Process

Two brief examples from current construction projects, told to co-author Toole during phone conversations with project contractor personnel, illustrate the importance of early consideration of construction safety. During the concept design of the Olmstead Dam project in Illinois, the project owner, the U. S. Army Corps of Engineers, stated their desire to have the project completed without ever putting scuba divers in the water to inspect the construction, which is typical on such dam projects. This safety goal led URS Corporation to decide to use very large precast concrete modules. A similar principle is associated with the Ivanpah Solar Electric Generating System being constructed in the Mojave desert. Bechtel's desire to reduce the amount of construction work performed at height led them to design the 450' tower to be assembled from very large prefabricated modules. Although the use of prefabricated modules on both projects will lead to substantial time, cost, and quality benefits as well, it is less likely that

the modules would have been pursued if construction worker safety had not been explicitly considered and valued during the concept design phase.

Collaboration Enhancing Processes. Although there was no formal DfCS program on the Hospital Project (the first case study discussed), the project did have several special elements that are particularly effective at enabling DfCS (and constructible and high-quality design in general). First, the designers and key construction personnel were co-located (i.e., had nearby offices) throughout the design. Second, the owner allocated sufficient time for the design stage, rather than constantly pushing for the design to be completed as soon as possible, which is common in the industry. Third, design and construction personnel had developed trusting relationships through a team-building retreat at the start of the design process. Fourth, the project personnel used collaborative decision-making tools associated with lean construction. Fifth, design and construction personnel shared common financial incentives that drove each party to pursue the goals of the project, not just those of their employer.

Although IPD is intended to maximize constructability input into a project's design, construction worker safety is not always explicitly included in the constructability review process (which it was on the Hospital Project). Appendix 23 provides text that could be added to a typical IPD contract to ensure that AEs participating in an IPD project recognize that construction worker safety must be a key design criterion. This text was based on the contract from the Hospital Project Case Study.

DfCS-Related Knowledge. Even if collaboration between designers and construction personnel is frequent and cordial, having DfCS performed efficiently will be difficult if designers possess insufficient knowledge of construction hazards, construction means and methods, and potential design alternatives to improve safety. Owner firms may wish to hire only AE firms that provide their design employees with training on construction safety. For example, the Washington Group subsidiary of URS has provided many of their design engineers with sixteen hours of construction safety training. Owners should also consider giving preference to AE firms that ensure the professional development of engineers (especially young employees) includes a field assignment in order to gain knowledge of construction means and methods. Finally, owners may wish to require AE employees to complete DfCS-training before they are allowed to work on the owner's projects, as BHP Billiton has required for AEs working on a large building program in western Canada. (The authors are currently conducting research on this training program.)

DfCS Tools. Given that most design professionals lack sufficient knowledge of construction safety and DfCS opportunities, owners should insist that design professionals have access to discipline-specific DfCS checklists. Such checklists can be created in-house or secured from external sources. The Construction Industry Institute DfCS tool developed by Professors J. Hinze and J. Gambatese provide a database of over 400 individual checklists, organized by construction phase (such as concrete, steel erection, etc.). The www.designforconstructionsafety.org website includes a spreadsheet containing 1700 DfCS examples and checklists that was compiled by Mr. Alan Speegle at the Southern Company.

Design managers should also consider providing their employees with reference tools and websites for increasing their employees' knowledge of construction safety in general and opportunities for designing for safety. Government agencies within the UK, Australia and Singapore have developed helpful tools that can be identified and accessed through links provided at www.designforconstructionsafety.org.

Many process/industrial construction owners have created lengthy and detailed risk assessment documents and require their use as part of a prescribed risk management process. These documents can serve as a tool to help designers follow a structured process to ensure all potential safety hazards are identified. It should be noted, however, that owners who wish to implement DfCS on their projects should not assume their existing capital project risk management documents and processes sufficiently address construction worker safety. The authors reviewed several such documents as part of their review of documents used by the Microchip Manufacturer, Power Generator, and Energy Company case study firms. With each set of documents, the authors found the vast majority of items were associated with the safety of users and maintenance workers, not with the safety of construction workers.

Information Technology Infrastructure: Owner, designer, and construction personnel must be able to easily access draft design documents and share DfCS-related and other constructability comments. A system must exist that facilitates tracking specific design suggestions from inception to closure. As such, a commercially-available project collaboration software package should be set up at the beginning of the design process, not at the start of construction.

An owner seeking to implement DfCS on a project should also insist that the designer and key contractor personnel use Building Information Modeling (BIM) software. Even in the time since the research reported here was initiated in 2008, the capabilities and use of BIM have grown substantially. The authors believe that BIM may prove to be the most important tool in the diffusion of DfCS. One reason is that BIM provides realistic 3D visualization that may allow designers and constructors to identify potential site hazards that are not obvious from viewing 2D plans. A second reason is that 4D BIM (which simulates the construction sequencing over time) is becoming more widely used, which allows designers and constructors to identify potential hazards not obvious from viewing static 3D renderings. A final reason why BIM may prove crucial to the growth of DfCS is that it is leading to the collaboration, during design, by designers and contractors that is so crucial for effective DfCS.

Acknowledgement

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Appendices

1 IRB documents

2 Sample request to participate in research as a case study organization

3 Case study survey

4 Case study interview script

5 Hospital project case study research methods details

6 Microchip manufacturer case study research methods details

7 Power generator case study research methods details

8 Energy company case study research methods details

9 Industry questionnaire

10 Sample industry survey request

11 Hospital project case study Survey data

12 Hospital project case study Interview compilation

13 Microchip manufacturer case study Survey data

14 Microchip manufacturer case study Interview compilation

15 Microchip manufacturer case study LCS documents

16 Power generator case study Survey data

17 Power generator case study Interview compilation

18 Energy company case study Survey data

19 Energy company case study Interview compilation

20 Industry survey data

21 Recommended changes to the EJCDC E-500

22 Recommended changes to the EJCDC E-700

23 Recommended changes to the hospital project case study IPD agreement

Appendix 1: Institutional Review Board Documents

HUMAN SUBJECTS RESEARCH **BUCKNELL UNIVERSITY**

IRB#_____

Form A-1: Research Review Status Self-Report

Principal Investigator (PI): T. Michael Toole
Department/Program: Civil & Env. Eng
Project Title: **Owners' Role in Facilitating Designing for Construction Safety**
Address: Dana 332
E-Mail: ttoole@bucknell.edu Phone: 7-3820

PI Status: Faculty _X_ Staff __ Student __Non-Bucknell __ (explain below)

Part A: To be completed by Principal Investigator

In my judgment, the above named research project (check one and append electronic copies of all required supporting documents):

Is exempt from expedited or full IRB review _____	(Form A-2)
Qualifies for expedited IRB review ___X__	(Form A-3)
Requires full IRB review _____	(Form A-4)

I certify that the statements herein are accurate and complete. I agree to protect the rights and welfare of the human subjects participating in my research, to abide by University guidelines for securing informed consent, to safeguard the confidentiality of my research data, and to inform the chair of the IRB should any changes in the research protocol or human subject issues arise during the course of this research.

Signature of Principal Investigator: T. M. Toole Date: 4/13/08

NOTE: The Sponsor and the Principal Investigator MUST be in agreement as to the research review status of the project BEFORE it is forwarded to the appropriate Departmental Reviewer.

Part C: To be completed by Departmental Reviewer

____ I agree with the research review status self-assessment(s) indicated above.

____ I disagree with the research review status self-assessment(s) indicated above, and have not been able to reach an agreement with the Principal Investigator and/or Sponsor. The full IRB will have to consider this research protocol.

Signature of Departmental Reviewer: _____ Date:_____

For ALL categories of review, including Exempt, please forward this signed form to the IRB Chair

HUMAN SUBJECTS RESEARCH **BUCKNELL UNIVERSITY**

IRB#_____

Form A-3: Checklist for Research Qualifying for Expedited Review with Guidelines for Protocol Preparation

Principal Investigator (PI): **T. Michael Toole**
Department/Program: Civil & Env. Eng
Project Title: **Owners' Role in Facilitating Designing for Construction Safety**
Address: Dana 332
E-Mail: ttoole@bucknell.edu Phone: 7-3820

PI Status: Faculty _X_ Staff __ Student __Non-Bucknell __ (explain below)

Directions: If you believe that your project qualifies for expedited review, please submit the following materials to the Departmental Reviewer: (a) a completed electronic copy of this form; (b) a signed copy of Form A-1 and a copy of your certificate of completion for the IRB online training program via campus mail. Please check all applicable items in Parts A and B and provide all relevant information in Part C. **Research activities will only be considered for expedited review when all items in Part A and at least one item in Part B apply.**

Part A:

1. __X___ The research does not involve prisoners, fetuses, pregnant women, the seriously ill, or mentally or cognitively compromised adults as subjects.

2. __X___ The research does not involve the collection or recording of behavior which, if known outside the research, could reasonably place the subjects at risk of criminal or civil liability, be stigmatizing, or be damaging to the subject's financial standing, employability, insurability, or reputation.

3. __X___ The research does not involve the collection of information regarding sensitive aspects of the subjects' behavior (e.g., drug or alcohol use, illegal conduct, sexual behavior).

4. __X___ The procedures of this research present **no more than minimal risk** to the subject (where minimal risk means that the probability and magnitude of harm or discomfort anticipated in the proposed research are no greater than those ordinarily encountered in daily life or during the performance of routine physical/psychological examinations or tests).

Part B (at least one item should apply)

1. ____ Research involving existing identifiable data, documents, records, or biological specimens (including pathological or diagnostic specimens), where these materials, in their entirety, have been collected or will be collected solely for non-research purposes. [**NOTE: These sources are not publicly available and, although confidentiality will be strictly maintained, information will not be recorded anonymously** (e.g., use will be made of audio-or videotapes, names will be recorded, even if they are not directly associated with the data.]

2. ____ Collection of data through use of the following procedures: a) non-invasive procedures routinely employed in clinical practice excluding procedures involving x-rays or microwaves; b) physical sensors that are applied either to the surface of the body or at a distance and do not involve input of significant amounts of energy into the subject or an invasion of the subject's privacy; c) weighing, testing sensory acuity, electrocardiography, electroencephalography, thermography, detection of naturally occurring radioactivity, electroretinography, echography, sonography, ultrasound, magnetic resonance imaging (MRI), diagnostic infrared imaging, doppler blood flow, and echocardiography; d) moderate exercise, muscular strength testing, body composition assessment, and flexibility testing where appropriate given the age, weight, and health of the individual.

3. ____ Collection of data from voice, video, digital or image recordings made for research purposes where identification of the subjects and/or their responses would not reasonably place them at risk of criminal or civil liability, be stigmatizing, or be damaging to the subjects' financial standing, employability, insurability, or reputation.

4. __X__ Research on individual or group characteristics or behavior (including but not limited to research involving perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior, or research employing surveys, interviews, oral history, focus groups, program evaluation, human factors evaluation, or quality assurance methodologies).

5. ____ Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior. [Although confidentiality will be strictly maintained, information will not be recorded anonymously, e.g., use will be made of audio-or videotapes, names will be recorded, even if they are not directly associated with the data).]

6. ____ Research that involves deception **[NOTE: Deception must be scientifically justified and de-briefing procedures must be outlines in detail.** Based upon the judgment of the reviewers, some protocols involving deception may qualify for expedited review. In other cases, the deception will be of sufficient consequence to require full IRB review.]

7. ____ Prospective collection for research purposes of biological specimens; research on drugs or devices for which an investigational new drug exemption or an investigational device exemption is not required; and collection of blood samples by finger stick or venipuncture.

8. ____ Research previously approved by the convened IRB as follows:
   (a) where (i) the research is permanently closed to the enrollment of new subjects; (ii) all subjects have completed all research-related interventions; and (iii) the research remains active only for long-term follow-up of subjects; or
   (b) where the research remains active only for the purposes of data analysis; or
   (c) where the IRB has determined at a convened meeting that the research involves no greater than minimal risk and no additional risks have been identified; or
   (d) where no subjects have been enrolled and no additional risks have been identified.

Part C

Please provide the following information. You may use additional sheets if necessary. For expedited research, submission of a formal research proposal is not required. However, if the information requested below is contained in clearly identified fashion in a research proposal, you may append the proposal in lieu of completing some or all of the items below as long as you indicate where in the proposal (give page, line numbers) the relevant information can be found.

1. What is the <u>purpose</u> of the proposed study (the research question) and what is the research hypothesis?

The aims of this research are to increase our understanding of owners' attitudes regarding Designing for Construction Safety (DfCS) and to create documents that will facilitate owners' use of DfCS on their projects. Specific objectives relating to owners' attitudes include:

1. To identify the approximate percentage of owners who are already aware of the design for construction safety concept.
2. To identify owners who are or become aware of the DfCS concept feel promising DfCS is as an intervention for improving safety on their projects. That is, to identify the percentage of owners who perceive the DfCS concept to be an important process for reducing construction injuries and improving the health of construction workers.

Informed Consent Documentation

Project Name: **Owners' Role in Facilitating Prevention through Design in Construction**

Purpose of the research: To increase our understanding of owners' attitudes regarding Prevention through Design (PtD) and to create documents that will facilitate owners' use of PtD on their projects.

General plan of the research: Three sets of empirical research will be conducted: pilot interviews of approximately a dozen owner firms, an email or telephone survey of 120 firms who are members of one or more of the national groups of owners and developers listed above, and real-time case studies of three owners going through design and construction processes that offer opportunities for implementing PtD. Deception will not be employed as part of the research.

Estimated duration of the research: **15 minutes to complete the survey** or 30-60 minutes to be interviewed. Participating in a case study will likely take between 3 and 15 hours.

Estimated total number of subjects: Approximately 120 survey subjects and a dozen interviewees.

The subject is encouraged to ask any questions at any time about the study and its procedures, or his/her rights as a subject. The Investigators' names and contact information are included below so that the subject may ask questions and report any study-related problems. The investigators will do everything possible to prevent or reduce discomfort and risk, but it is not possible to predict everything that might occur. If a participant has unexpected discomfort or thinks something unusual or unexpected is occurring s/he should contact:

Prof. Mike Toole, Civil & Env. Engineering, Bucknell University, Lewisburg, PA 17837, 570-577-3820, ttoole@bucknell.edu OR
Dr. John Gambatese, Civil, Construction and Environmental Engineering, Oregon State University, 202 Apperson Hall, Corvallis, OR 97331, Tel.: (541) 737-8913, john.gambatese@oregonstate.edu

Subject participation is voluntary. Anyone who agrees to participate in this research may change his/her mind at any time. Subjects may refuse to answer any questions and/or withdraw from the study at any time.

Participants will receive no payment for participating in this research. The Investigators believe the research results will benefit the construction industry by improving safety and health on construction sites.

The information in the study records will be kept confidential. Data will be stored securely and will be made available only to persons conducting the study unless the subject specifically gives permission, in writing, to do otherwise. No reference will be made in oral or written reports which would link the subject to the study. However, the identities of participants who express a desire to participate in future research on designing for construction research will be shared with the research sponsors and/or members of workgroups within the OSHA Construction Alliance Roundtable who perform additional research on PtD.

I have read the above description of the research. Anything I did not understand was explained to me by and I had all of my questions answered to my satisfaction. I agree to participate in this research, and I acknowledge that I have received a personal copy of this consent form.

By signing below, I affirm that I am at least 18 years of age or older.

Signature of Subject: _____ _____
(Date)

d) methods for obtaining informed consent and assent in the case of minors. For minors, indicate how the consent of parents or legal guardians will also be obtained. **Append electronic copies of all materials used to obtain informed consent or assent. Model consent and assent forms can be found in the Appendices (Forms B-1, B-2, and C).**

The research will not involve minors.

e) methods for preserving confidentiality (including plans for storing/disposing of tapes and other data records at the conclusion of the research).

The data will be treated as confidential in that the completed survey or interview notes for individuals will not be shared outside of the two PIs and their student assistants. However, the data collection documents will not be destroyed in case additional research is undertaken. Moreover, the identities of participants who express a desire to participate in future research on designing for construction research will be shared with the research sponsors and/or members of workgroups within the OSHA Construction Alliance Roundtable who perform additional research on DfCS. The above information will be communicated on the Consent form and written permission will be obtained from individuals willing to have their identities and interest in DfCS shared outside of the research team.

f) if deception is to be employed, provide a scientific justification for its use and describe debriefing procedures. **[NOTE: If the research is such that debriefing cannot be carried out, the project must be submitted for full committee review.]**

Deception will not be employed.

5. Indicate any benefits that are expected to accrue to subjects as a result of their participation in the research. In the event that subjects will be paid, describe all payment arrangements, including how much subjects will be paid should they choose to withdraw from the study prior to completion of the research.

Participants will not be paid. The initial communication with subjects will indicate that the researchers believe the research results will benefit the construction industry by improving safety and health on construction sites.

6. Describe any relationship between researcher and subjects, such as: teacher/student; superintendent/principal/teacher; employer/employee. If such a relationship exists, how will it affect the subject's ability to participate voluntarily and how will the principal investigator handle it?

It is expected that all subjects will be true volunteers in that they can easily refuse to participate without any personal or professional repercussions. Subjects who are requested to participate in pilot interviews or email surveys may refuse during the initial contact and their identities will not be communicated outside of the research team. Case study participants will consist only of individuals who agree in writing to participate based on their interest in DfCS.

Note to PI: Please append to this document any additional information that is applicable (consent forms, debriefing scripts, survey instruments, etc.), and submit it all to the Departmental Reviewer as a single, paginated Word file. Please give the file a unique filename in this format: [e-mail username]+[date].doc (Example: smithj12-07-04.doc; do not use "slashes" in the date, as this will create an invalid filename)

A draft consent form is attached.

Note to Departmental Representative: Please forward this file electronically to the Chair of the IRB, and forward via campus mail a signed copy of Form A-1 and a copy of the certificate of completion for the online IRB training program.

3. To identify the extent to which owners feel they can insist that the architect/engineers (AEs) they contract with for design services perform DfCS on their projects.
4. To identify the perceived and actual barriers that might prevent owners from implementing DfCS on their projects.
5. To identify the range of premiums, either in designer fees or construction cost, that owners will accept for implementing DfCS.
6. To identify how owners' opinions and acceptance of DfCS vary with organizational characteristics.

2. Describe the proposed subject sample. If subjects under the age of 18 will participate in your research, indicate the sample1s expected age range.

Members of at least six national groups of owners and developers will be asked to participate in this research: Construction Users Roundtable(CURT), Associated Owners and Developers (AOD), Construction Industry Institute (AOD), Government Service Administration (GSA), Department of Defense (DOD) facilities management offices, and the state departments of transportation for Pennsylvania and Oregon. All participants will be over the age of 18.

3. How will subjects be recruited and selected?

The Executive Director (or equivalent position) for each of the groups listed above will be contacted via telephone and email, briefed about the research objectives and methodology, and asked if their organization will facilitate their members' participation in the research by providing the researchers with member names and email addresses. In addition, the researchers will ask for the names of individual members who may be willing to be interviewed as part of the pilot research stage. Once the names and email addresses are obtained, the researchers will send emails containing the survey to all members of each group. It is expected that individuals and companies willing to participate in case studies will be identified during the pilot interviews or the surveys.

4. Describe fully the following:

a) all research methods and procedures that will be employed in this study.

Three sets of empirical research will be conducted: pilot interviews of approximately a dozen owner firms, an email or telephone survey of 120 firms who are members of one or more of the national groups of owners and developers listed above, and real-time case studies of three owners going through design and construction processes that offer opportunities for implementing DfCS.

b) approximately how much time each subject is expected to devote to the research.

It is expected that pilot interviewees will spend 1-2 hours talking with the researcher, that survey participants will spend 20 minutes completing the survey, and that case study participants will spend 10-15 hours on the research.

c) how data will be collected and recorded (with or without identifiers? what instruments, materials, or equipment will be used? will audio- or videotapes be employed in data collection?). **Append electronic copies of all written instruments (if you do not have them in electronic form, forward copies via campus mail) and/or describe any apparatus with which subjects will be in direct contact.**

The written survey will be administered via email. Pilot interviews will occur either in the interviewee's office or via a telephone conversation and use the draft written survey as an outline. Case studies will likely involve the PI traveling to the offices of the owner and/or architect/engineers for interviews and to observe design progress meetings.

The draft written survey is attached.

Appendix 2: Sample request to participate in research as a case study organization

Details about the DfCS Case Study Process and Goals

Researchers at Bucknell University and Oregon State University are conducting a research study titled "Owners Role in Facilitating Designing for Construction Safety." The research, which is funded by the National Institute for Occupational Safety and Health and the Center for Construction Research and Training, aims to investigate the role that owners and developers of capital projects can play in promoting designing for construction safety (DfCS) on their projects. DfCS is a process in which architects and engineers (A/Es) explicitly consider the safety and health of construction workers as they make design decisions on the permanent features of the facility. The results of the study will be used to develop several practical resources including a "How to Guide" for use by owners/developers to assist them in having their projects designed for safety during construction.

One of the specific aims of the research is to write case studies of firms who are pioneering in implementing DfCS programs. Two types of cases—teaching cases and business cases—will be written about each firm. Each case study type has a different purpose and set of contents. Teaching cases will be intended for engineering and architecture educators teaching their students about DfCS. As is true for most effective teaching cases (cite), these cases will focus on a moment in the professional life of an individual, typically a senior manager. The moment will be associated with a specific decision regarding a DfCS program that the manager needs to make, for example, how to improve, expand or better market his or her program. The case will provide details about the company's DfCS program, including the resources needed and/or deployed, how employees were trained, how the firm marketed the program to clients, and the barriers to implementing the program. The case study will also include general information about the construction industry and the firm's operations in order to help the reader understand the case study's managerial context. Unlike business cases, which include a clear message on what is the right thing for a manager to do, these teaching case studies will include sufficient information and perspectives that the proper course of action is not obvious, and therefore can serve as an effective tool for stimulating discussion.

A second type of case studies that will be developed—business case studies—will be targeted towards managers who are considering implementing DfCS within their firms, that is, for potential adopters of DfCS. The goal will be to show that implementing DfCS is feasible and makes good business sense. Unlike teaching cases, business case studies typically do not focus on one moment in time or on an individual manager. Rather, the cases will describe the implementation of a DfCS program within a firm, including the costs associated with each element in the program and the benefits (reduced injury rates, reduced workers comp and other insurance rates, reduced project delays, increased sales, etc.). The costs and benefits will be estimated when necessary but provided in sufficient detail to allow conventional financial analysis, such as Net Present Worth or Rate of Return. The cases will mention mistakes made or challenges experienced only in passing, if at all. The goal of each case is to let the written facts persuade the reader to decide to implement DfCS within his or her firm.

The process for gathering information to allow the Investigators to write both types of case study is summarized below.

1. The researcher will send the case study liaison the case study purpose, an outline of planned content, and a list of documents and interviews needed.
2. The case study liaison will assemble and forward as many of the necessary documents as possible to the researcher and will schedule interviews at the case study office.
3. The researcher will travel to the case study office and construction sites to perform the scheduled interviews and to review documents that could not be shipped previously.
4. The researcher will draft both the teaching and business cases and communicate to the liaison what information is still needed.
5. The liaison will assemble the missing documents and schedule additional interviews as necessary.
6. The researcher will travel a second time to the case study office and/or construction sites as necessary to complete interviews and document review.
7. The researcher will complete and forward the draft case studies the liaison for feedback.
8. The case studies will be finalized and posted on the grant website.

The time commitments associated with being a case study should not be excessive. The firm's case study liaison with the researchers will likely require approximately 10 hours of his or her time to collect the needed documents, arrange for the interviews, be interviewed, read and comment on the case study draft, and have the draft reviewed by other firm managers before it is released. Each of the interviews of approximately 6-12 firm employees and employees of other organizations associated with the DfCS program will likely last approximately one hour. The researchers will travel to the firm's office to conduct the interviews.

Completed case studies will likely be posted on www.designforconstructionsafety.org, the OSHA Alliance DfCS workgroup webpage and a NIOSH NORA webpage as well as distributed to architectural and engineering educators over time. It is the Investigators' expectation that case studies will portray firms in a positive way; however, all firms will have the right to require that case studies written about their firm maintain the anonymity of the firm if desired. Specifically, firms can require the researchers disguise the identity of the firm, the identity of some or all individual employees, and/or specific information about individual projects or the overall organization that might otherwise allow readers to identify the name of the firm.

Appendix 3: Case Study Questionnaire

Design for Construction Safety Survey

Researchers at Bucknell University and Oregon State University are conducting academic research on Design for Construction Safety (DfCS). DfCS is a process in which the safety and health of **construction workers** is explicitly considered during the design of the permanent features of the facility. For example, engineers may design steel connections to allow for safe access and installation by steel erectors. Other examples might include locating pipe values to minimize obstructions and prefabricating stairs to include handrails. Some safety professionals believe DfCS can help make construction sites safer and less unhealthy.

We would very much appreciate your sharing your views of DfCS by answering the questions below. We anticipate the survey will take you approximately 10-15 minutes to complete. Your answers will be kept confidential; the data will be used only for aggregated statistical analysis and will not be released outside of the research team. If you have any questions or concerns, please do not hesitate to ask. Contact information for the principal investigators is provided at the end of this survey.

For questions that refer to "your organization" please answer based on your permanent employer (the highest level, i.e., parent company), not your current project team.

Thank you for taking the time to participate!

1. Had you heard of Design for Construction Safety (DfCS) before this survey? Please place a check by the statement that best reflects how you feel.
   - ___ I had never heard of DfCS.
   - ___ I had heard of DfCS but my organization has never considered implementing it.
   - ___ My organization has considered implementing DfCS but has never done so.
   - ___ My organization has been involved with DfCS on a limited basis.
   - ___ My organization routinely ensures DfCS occurs on our projects.

2. Which statement best matches your overall attitude toward the DfCS concept?
   - ___ The potential benefits of DfCS do not seem compelling to me.
   - ___ The benefits of DfCS sound promising but there are too many barriers to try implementing it.
   - ___ The benefits of DfCS sound like a good idea. I would consider trying it.
   - ___ DfCS sounds like a winner. I have already or will likely try to implement it

3. If your organization formally addresses construction worker safety and health in the design of its projects, what process/resources does it use? Please check all that apply.
   - ___ Construction worker safety is part of the architect-engineer (A/E) scope of work per their contract
   - ___ Design checklists
   - ___ Constructability reviews
   - ___ In-house design guides
   - ___ Computer program. Name of program: _____
   - ___ Other: _____
   - ___ No specific process/resources

4. If your organization implements DfCS on projects, how important is DfCS to construction worker safety and health compared to other safety and health programs/processes that are currently implemented? DfCS is:

___ Not at all important
___ Less important
___ About the same importance
___ More important
___ Significantly more important
___ I don't know

5. What motivates, or would motivate, your organization to implement DfCS on its projects? Please check all that apply.

___ Competitive advantage
___ Improved construction worker safety and health
___ Improved facility occupant safety and health
___ Improved quality of construction
___ Enhanced organization reputation
___ Reduced project cost
___ Shorter project schedules
___ Other: _____

6. What do you feel are the most important barriers to implementing DfCS on your organization's projects?

_____
_____
_____
_____
_____

7. Please place a check by the statement that best reflects how you feel about whether typical contract clauses hinder the use of DfCS.

___ The language in my company's typical design and construction contracts explicitly rejects the idea of A/Es having anything to do with safety and this won't change.
___ It would take a lot of work, but the typical language in my company's contracts that conflicts with A/Es performing DfCS could be changed.
___ It would be easy to modify my company's typical contract language to allow A/Es to perform DfCS.
___ It would not be necessary to change my company's typical contract language to allow an A/E to perform DfCS.

8. Would you support modifications to standard A/E contract documents (i.e., those promulgated by the American Institute of Architects and the Engineers Joint Contracts Document Committee), to allow A/Es to voluntarily perform DfCS on a project while limiting their liability? Please place a check by the statement that best reflects how you feel.

___ Yes, I would support such modifications regarding DfCS.
___ Yes, I would support modifications regarding DfCS if they did not impact other aspects of the A/E's role and responsibilities on a project.
___ Yes, I would support modifications regarding DfCS if they did not impact my organization's roles and responsibilities on a project.
___ No, I would not support modifications to the standard contract documents.
___ I am not familiar with the standard contract documents.

9. Please place a check by the statement that best reflects how you feel about potential A/E resistance as a barrier to DfCS.

___ A/Es will never agree to perform DfCS and my organization cannot force them to do it.
___ A/Es will resist, but my organization can insist the A/Es we work with perform DfCS.
___ Some A/Es my organization works with will agree to perform DfCS while others will not.
___ Most of the A/Es my organization uses will gladly perform DfCS.

10. Please place a check by the statement that best reflects how you feel about whether A/Es are capable of performing DfCS.

___ Most A/Es could never learn enough to effectively perform DfCS.
___ It would take a lot of effort, but most A/Es could learn enough to effectively perform DfCS.
___ Most A/Es could perform DfCS with assistance from others, e.g., Construction Managers and contractors.
___ Most A/Es could easily learn enough to effectively perform DfCS.
___ Most A/Es are already capable of effectively performing DfCS.

11. If a typical owner was reasonably confident that DfCS would reduce total **project** costs (design and construction) by 2%, he or she would likely be willing to pay A/Es up to _____% more in **design** fees to perform DfCS. (please enter a percentage)

12. Please place a check by the statement that best reflects how you feel about whether potential increases in A/E fees are a barrier to DfCS in the industry.

___ A/Es would need to increase their fees so much to perform DfCS that it will never happen.
___ It would take a lot of work, but the higher design fees associated with A/Es performing DfCS could become acceptable.
___ The increased design fees associated with DfCS could be justified to higher management.
___ A/Es would not need to increase their fees and/or the modest increases would not be a problem at all.

13. Please place a check by the statement that best reflects your concerns about your organization's liability with respect to DfCS.

___ I believe that addressing construction worker safety during design is likely to <u>increase</u> my organization's liability exposure.
___ I believe that whether or not construction worker safety is addressed during design <u>will not affect</u> my organization's liability exposure
___ I believe that addressing construction worker safety during design is likely to <u>decrease</u> my organization's liability exposure.

14. If your organization considered DfCS but decided not to implement it, what were the reasons for not implementing it? Please select all that apply.

___ Not applicable to my organization
___ Too costly
___ Added design duration
___ No perceived benefit to my organization
___ Not enough information or knowledge about DfCS
___ Other project objectives had higher priority
___ Other: _____

15. What priority does your organization place on the following criteria with respect to its construction projects? Please rank the criteria with 1 being the highest priority, 2 the second highest priority, and so forth.

___ Aesthetics
___ Construction worker safety and health
___ Facility user safety and health
___ Maintenance worker safety and health
___ Project cost
___ Project schedule
___ Quality of the final product
___ Other: _____

16. If a substantial portion of the industry elected to perform DfCS on projects, how ***might*** the following items change? Please check one box in each row.

	Decrease	No Change	Increase	I don't know
Construction injuries				
Design costs				
Construction costs				
Total project costs to the owner				
Design durations				
Construction durations				
Total design and construction durations				
Construction quality				
The number of lawsuits against owners				
The number of lawsuits against A/Es				
The reputation of A/Es within society				
Other:				

17. What changes to your organization's structure and/or project development process were made, or would be needed, in order to implement DfCS on projects?

_____
_____
_____

18. What would enable or assist your organization to better implement DfCS on your organization's projects?

_____
_____
_____

Thank you again for helping us to improve construction safety by participating in this survey!

If you have any question or comments, please contact us anytime:
Prof. Mike Toole, Bucknell University, mike.toole@bucknell.edu, 570-577-3820
Prof. John Gambatese, Oregon State University, john.gambatese@oregonstate.edu, 541-737-8913

Appendix 4: Case Study Interview Script

Name _____ Organization: Date:

Introduction: I am part of a team of researchers at Bucknell University and Oregon State University conducting academic research on Design for Construction Safety (DfCS) as part of research grant funded by the National Institute for Occupational Safety & Health via the Center for Construction Research and Training. DfCS is a process in which architects and engineers (A/Es) explicitly consider the safety and health of **construction workers** as they make design decisions on the permanent features of the facility. We appreciate your willingness to be interviewed about your views of DfCS. Your answers will be kept confidential and will not be released outside of the research team. For questions that refer to "your organization" please answer based on your permanent employer, not your current project team.

Drivers

Who is the primary driver of designing for construction safety in your organization?

What do you think is their primary motivation for pursuing DfCS?

What is your primary motivation for participating in DfCS?

Would DfCS have been implemented if the primary driver was not interested in it?

Processes

What did the primary safety driver do initially to initiate and enable DfCS?

How do DfCS opportunities get identified?

How are DfCS decisions made? Who makes them and how are meetings, emails or phone conversations used?

What is the form and content of DfCS information that is communicated?

What phases of construction have had DfCS consideration? Why?

What DfCS -related information was initially possessed by each of the following entities? What about now?

Owner

A/E

GC/CM

trade partners

Barriers/Enablers/Impacts

How is safety addressed relative to other priorities such as cost, schedule, and quality?

What do you feel are the most important barriers to implementing DfCS on your organization's projects?

What changes to your organization's structure and/or project development process were made, or would be needed, in order to implement DfCS on projects?

What would enable or assist your organization in implementing DfCS on your organization's projects?

What have been, or do you foresee will be, the impacts of implementing DfCS?

Project

How are your organization's projects different than typical construction projects?

How have these differences affected the application of DfCS?

If you could change your organization's processes immediately, what DfCS-related thing would you differently?

Are there any aspects of DfCS that we have not talked about that you feel should be discussed?

Appendix 5: Hospital Project Case Study Research Methods Details

Description of project or group interviewed

All interviewees were associated with hospital design and construction project located in a West Coast city. The project owner is an affiliate of a very large health management organization. The $1.7billion health care facility was in the design phase during the interviews in August 2009 and construction was scheduled to start approximately eight months later. This project was chosen to be a case study after a project manager with the general contractor approached one of the researchers after hearing a talk about design for construction safety (DfCS) at a steel construction conference. The individual asked for additional information about the DfCS concept. After several conversations, the researchers agreed to give a presentation on the topic at the project site in exchange for the opportunity for project personnel to voluntarily participate in an anonymous survey and/or to be interviewed the day before the presentation.

The project is unusual in that it is following a lean construction integrated project delivery (IPD) method. Lean construction is a radically innovative project system in which lean production principles and processes underlie everything that occurs on site. (Readings posted on the Lean Construction Institute—www.leanconstruction.org/readings.htm—provide effective background information). IPD is an innovative alternative delivery process in which key construction personnel (including the general contractor/ construction manager and steel, concrete, electrical, HVAC, plumbing and other subcontractors) are co-located with architectural and engineering design professionals during the design. (Wikipedia provides an effective summary of the IPD concept and processes.) With the traditional design-bid-build process, construction personnel are rarely involved with the project until the design is completed because the owner awards the contract to the general contractor based on bids given for the completed design documents. Even with typical design-build projects, the integration of constructability input into the design from the firms who will perform the construction is relatively limited with regards to the number of firms involved and the amount of detailed feedback that is given.

All key design and construction personnel associated with the project during the design phase were required to participate in several days of training on lean construction principles and processes. All personnel were also informally required to commit to using lean construction tools, such as the Last Planner and specific design decision analysis templates. The contracts between the owner and all key design and construction firms provided significant bonuses if the completed project met aggressive budget and deadline goals. As such, all firms were highly motivated to collaborate to achieve these goals.

Documents reviewed

The researchers were not provided with any documents associated with the project before the onsite interviews occurred in August 2009. While on site, they attended a weekly operations meeting and were given a copy of the handouts for the meeting.

Interview process

The researcher's project contact arranged the interview schedule based on input from the researchers. It was initially communicated that the researchers were primarily interested in interviewing representatives from the owner organizations, however, after discussing the project with the researcher's contact, it was agreed it would be more appropriate to include

representatives from most of the design and construction firms who were actively participating in the design stage. The interviews occurred in two empty offices in the building where the project personnel were located during the design phase. Interviewees had received an email alerting them that researchers would be on site conducting interviews and an individual email or phone request from the researcher's contact, along with an informed consent form. When one representative from a firm came at the scheduled time, the interview was conducted jointly by the two researchers. When more than one representative showed up, the researchers split up and interviewed one person each. Handwritten notes were made on the interview script, under each question that was posed. Each interview typically took approximately thirty minutes. Not all questions were asked for many interviewees because the 30-minute session ended and the next interviewee was waiting at the door. The handwritten notes were later typed up by the interviewer and compiled into a document that provided all of the answers provided by the set of interviewees for each question.

As mentioned above, the researcher's contact arranged for all of the interviews. The sample was intended to be a quota sample in that the contact sought to ask at least one representative from each of the organizations present on site, but that the individuals who ended being interviewed were those were available on the days that the interviewers were present and during a timeslot that had not already been scheduled. The interviewers recorded the interviewee's employer on the interview notes sheet. A comparison of the set of interviewees with list of employers on site indicates that sample was fairly representative of the groups involved in the project.

This was the first use of the generic interview script that had been developed, which can be found in Appendix __.

Survey Process

The survey was conducted by having the researchers' contract send the email pasted below to all project participants, which numbered approximately seventy-five. A follow up email was sent approximately one week later.

> Dear Colleagues;
> (owner organization) & IPD team agreed to participate in an academic research on **Design for Construction Safety (DfCS)** by researchers at Bucknell University and Oregon State University. DfCS is a process in which the safety and health of construction workers is explicitly considered during the design of the permanent features of the facility. For example, engineers may design steel connections to allow for safe access and installation by steel erectors. Other examples might include designing noise reduction measures into large manufacturing facilities, designing barriers for moving parts or process work areas, or designing HVAC unit locations to provide safe maintenance access. Some safety professionals believe DfCS can help make construction sites safer and less unhealthy. We would very much appreciate your sharing your views of DfCS by answering the questions in the link below. We anticipate **the survey will take you approximately 15 minutes to complete**. Your answers will be anonymous; it will not be possible to identify any individual who completes the survey. If you have any questions or concerns, please do not hesitate to ask.
> http://www.surveymonkey.com/s.aspx?sm=92Th0_2fR4ap6YlzDTXB_2fkNQ_3d_3d
> We request you **complete the survey by Friday (8/7) 5:00 pm** and appreciate if you drop me a line when you complete it. Many thanks in advance.

As noted in the text above, the survey was administered using surveymonkey.com. The survey questionnaire used was a modified version of the generic form developed earlier during the research. The modifications were made to take into account that the majority of individuals

requested to participate in this case were not employees of the project owner organization. A copy of the survey is included in appendix ___.

As stated earlier, all project participants were requested to complete the survey. Because the survey is anonymous, it is not possible to identify which individuals participated; however, the demographic questions at the end of the survey provide insights into the sample characteristics. As shown in the data summary provided in the appendix, 8% of the participants were employed by the owner organization, 33% were designers and the remainder consisted of construction personnel mostly associated with the GC/CM organization. The organizations were fairly large: with one exception, the number of employees ranged from 150 to 43,000. Interestingly, the majority of organizations worked in all four construction markets: commercial, industrial, infrastructure and residential construction, with commercial accounting for most of their work. The percentage of projects that used an IPD approach ranged from 2-90% and averaged 40%. The companies ranged widely in the percentage of their projects that used their own employees as workers. Most of the companies worked on the West Coast or adjacent regions. No firms had international operations.

Appendix 6: Microchip Manufacturer Research Methods Details

I. Background

Site and Project Description

This case study focuses on a multi-national private owner organization ("owner") that manufactures microchip processors and other electronic technologies for the computer and electronics industry. The firm is the world's largest semiconductor chip maker (by revenue). Its headquarters are located on the West Coast, and design, manufacturing, and support facilities are located worldwide.

The focus for this case study is one of the firm's facilities in the Pacific Northwest. At this facility, the firm researches, develops, and conducts initial manufacturing of many of its new products. After new products and their manufacturing lines have been developed, the manufacturing processes are moved to other facilities around the world for production. Located at the Oregon facility are many buildings that house clean rooms, manufacturing facilities, research labs, support services, and offices. The site contains several large microchip manufacturing buildings.

Located at the site is a large group of Owner employees who oversee and support the design and construction of new buildings and renovation of existing facilities. These employees act as the owner's representatives during projects, working closely with the hired designers and contractors, and the Owner internal users of the facility to make sure that their needs are met.

Two types of projects are typically conducted at the site: basebuild and tool install/re-install. Basebuild projects are those in which a new building is designed and constructed. The buildings can range from small offices and support buildings to very large microchip fabrication buildings. After their construction, the buildings are outfitted with "tools" for manufacturing microchips (tool install). Tool install projects are smaller in size, but can require detailed design to ensure that the very expensive tools are correctly and safely placed and are readily usable. Tool re-install projects are those in which the current tools are replaced with new and/or upgraded tools for new fabrication lines. Tool install/re-install projects occur relatively frequently as the company tries to develop new microchips for the market. Other types of projects also occur on the site such as for regular maintenance, office renovation, and office expansion.

Throughout the local design and construction community, the Owner is known for being a very proactive and involved owner. A team of construction support personnel is assigned to each project that represents all of the affected design scopes (e.g., civil/structural, process/piping, mechanical/electrical, tools, architectural). The team works closely with the consultants and contractors to ensure that the Owner's needs and desired quality are met. In addition, the Owner is known for being highly involved in terms of worker safety and health, and for expecting a higher level of safety performance on projects than is typically expected by owner clients. The Owner's efforts have led to superior safety records on their projects.

Existing Design for Construction Safety Process

In the early 2000's, the Owner developed and implemented a DfCS process titled "Life Cycle Safety" (LCS). The motivation for this effort was to ensure a safe facility throughout the lifecycle of the facility (construction, operations, maintenance, renovation, decommissioning, and demolition). The Owner also wanted a formal process to obtain feedback from stakeholders regarding safety and health during each lifecycle phase of the facility. In addition, LCS was implemented to carry the Owner's injury-free culture through the programming, planning, and design phases.

The LCS process entails a series of design review meetings in which safety and health risks are identified, discussed, and mitigated. The meetings are attended by representatives from all parties on the project, and occur during multiple phases early on in the project. Early involvement of trade contractors to assist with conducting design reviews is a key component of the process. A variety of checklists and risk assessment tools were developed to assist the project team in improving safety and health in the design within the overall goals of the project. A more detailed description of the LCS process is available in the Appendix.

Since its initial development and implementation on a large microchip fabrication facility construction project at the Pacific Northwest site, the LCS process has been implemented on other projects and at other facilities around the world. Some modifications to the original process have been made to both tailor it to the particular sites and reflect modified contracting processes.

II. Case Study Process

A multi-activity process was used to conduct this case study that consisted of interviews with key project personnel, a review of LCS program documents and reports, and a general survey of Owner personnel.

Interviews of Key Project Personnel

The interview process began with the researchers contacting several personal contacts at the Owner firm who are currently or previously involved in the LCS process. These individuals provided the names and contact information of other key Owner employees to interview along with several non-Owner CM and designer personnel who are familiar with the LCS process. Each of the outside design and construction personnel had offices on the Owner's campus as they were currently involved in some of the Owner's projects. The list of interviewees included: seven Owner employees, four CM personnel, and four designer personnel. Each of the interviewees was contacted via e-mail and telephone to solicit their interest and availability for an interview. The researchers scheduled the interviews to occur over several days at the Owner's campus.

An interview script was developed to facilitate conducting the interviews and to maintain consistency between interviews. The script contained the same questions as that of the other case studies in this research study. Minor modifications were made to the wording of the questions to reflect the focus on Owner's LCS process and the typical Owner project. Each person contacted for an interview was e-mailed a copy of the script before the interview to give

them an idea of the questions to be asked and allow them the opportunity to prepare for the interview. A copy of the interview script is provided in the Appendix.

Document Review

The researchers also reviewed documents associated with the LCS process. Several forms developed when the LCS process was originally created and implemented were reviewed. These include the Option Evaluation Sheet, Risk Comparison Form, and Risk Mitigation Form shown in the Appendix. The researchers were also given an opportunity to view a typical contract used to procure design services to understand how the owner communicates safety expectations. A copy of the contract is not included in this report as it is considered confidential by the Owner. Lastly, a copy of a research report on the LCS process was reviewed. The report is from a research study conducted by one of the researchers and colleagues at the University of Oregon which aimed at assessing the effectiveness of the LCS process. The report provides a description of the LCS process along with assessments of its impact and benefits.

Survey of Owner Personnel

A survey of Owner personnel was conducted to gain an understanding of their perspective of the overall DfCS concept. The survey questions were similar to those of the other case studies and modified to reflect the Owner's design and construction process. A copy of the survey questionnaire is provided in the Appendix. Those interviewed were given a copy of the survey (by e-mail and hardcopy at the interview) to complete themselves. They were also asked to distribute the survey to others with whom they work, but no additional completed surveys were received by the researchers.

Interviews were scheduled over several days and conducted on the Owner's campus. A total of eight interviews were conducted, five from the Owner firm and three from the CM firm. Employees of the Owner firm who were interviewed included an Instrumentation and Control (I&C) lead, Process/Piping lead, Civil/Structural/Architectural lead, Design Manager, and Corporate EHS Manager. Those from the CM firm who were interviewed included an Electrical Superintendent, Commissioning Manager, and EHS Manager. Many attempts were made to schedule interviews with representatives of the design firms. However, no interviews with designers were conducted because time availability of the designers contacted and a general lack of interest.

Appendix 7: Power Generator
Case Study Research Methods Details

Note: DfS = Design for Safety, which is the term used by the firm to refer to their DfCS program.

I. Background

Site and Project Description

This case study focuses on an energy producing company that provides electricity to multiple areas within the southeastern part of the U.S. The firm is one of the nation's largest generators of electricity and participates in all phases of the electric utility business with more than 42,000 megawatts of electric generating capacity. Its headquarters are located in a large city in the southeastern United States, and design and other service facilities are located throughout the South.

The firm's main design office is located in the southeastern United States. At this facility, engineering and project management staff plan and design new facilities and renovation/maintenance projects. In-house construction personnel who oversee the construction activities are located primarily at the different construction sites. Construction personnel are periodically at the main design office to meet with engineering and project management staff. The firm also hires design consultants to perform some of its design work. For most of its construction work the firm will contract with general contracting and construction management firms to perform the work. The firm's construction personnel act as the owner's representatives during projects, working closely with the hired designers and contractors.

The power company regularly has a wide range of projects at its many facilities. The construction of entirely new facilities is uncommon with most of the current work being renovation and upgrade projects and maintenance projects. A recent significant effort has been the installation of scrubbers at the firm's plants to clean exhaust gases as required by the EPA.

The current projects under consideration for this case study are the installation of two new scrubbers and additional plant renovation and maintenance work at one of the firm's large coal-fired power plants in Georgia. The construction work has been successfully completed and the systems are now in operation. The firm's design for safety program was implemented during the design of the projects.

Existing Design for Construction Safety Process

The firm implemented a Design for Safety (DfS) program in 2005. The intent of the program is to alert design personnel of construction worker safety, operations safety, constructability, lessons-learned, and code requirements that shall be incorporated into their designs. The power company has implemented a Target Zero safety program intended to eliminate injuries in the workplace. The DfS program is an engineering effort that supports the Target Zero safety goal.

The DfS program encompasses a variety of activities and includes multiple resources. No later than 25% completion of the design, a meeting is conducted of the key design personnel and construction personnel on the project. Prior to the meeting, the design leads review a design for

safety checklist that was created which contains prompts to query the designers regarding aspects of their design. The designers also are instructed to search a DfS/lessons-learned database for applicable suggested designs. A meeting, titled the Hazard Identification and Constructability Considerations meeting, is then conducted in which the design plans and specifications are reviewed for safety, and the applicable checklist and database items are discussed. Agreed upon modifications to the design are made following the meeting. A more detailed description of the DfS program is provided in the Appendix.

A web page describing the DfS program was set up on the firm's intranet which describes the program and provides assistance to those involved. In addition, an internal DfS team was established to implement and monitor the DfS program, maintain and update the checklist and database, and provide assistance to project personnel.

In 2007, prior to the current research study, the researchers were asked to visit the power company's design office to evaluate the DfS program. At that time the firm was still in the initial implementation phase of the program on several major projects. The researchers attended several meetings and met with key DfS personnel. At the conclusion of their meetings, the researchers provided the firm with a variety of suggestions for improving and augmenting the program. Since that time the DfS program has been slightly modified in response to the recommendations and implemented more thoroughly within the firm. The current research study is an evaluation of the DfS program, its outcomes, and the lessons learned following its full implementation.

II. Case Study Process

Interviews of Key Project Personnel

The researchers conducted interviews of key project personnel knowledgeable about and involved in the DfS program. The researchers initially contacted a project manager (PM) within the firm to request participation in the study. The PM assisted by setting up interviews and meetings to conduct the case study at the design office in a southern city. In addition, a site visit to a power plant in the south was set up to view the construction work and meet with on-site construction personnel. The list of interviewees included: engineering managers, project managers, design technical leads (civil, mechanical, electrical, and instrumentation and controls), and construction managers, engineers, and safety personnel. The interviews and site visit were scheduled over several days at the design office and power plant site.

An interview script was used similar to the energy company case studies. The interview script facilitated conducting the interviews and maintaining consistency between interviews. Minor modifications were made to the wording of the questions to reflect the focus on the power company's DfS process and the typical power company project. A copy of the interview script was sent to the PM before the visit for review and approval. A copy of the interview script is provided in the Appendix.

Document Review

The researchers were also able to review documents related to the DfS program during their visit. Excerpts from the DfS checklist along with a description of the DfS program were reviewed. In

addition, the researchers reviewed the prior documentation and report from their initial evaluation of the DfS program in 2007.

Survey of Owner Personnel

The case study investigation also included a survey of project personnel. The intent of the survey was to gain a general understanding of key personnel perspectives beyond those interviewed, and to focus more on the DfCS concept as opposed to the firm's DfS program. A survey questionnaire was developed with questions similar to those of the energy company case study. The questions were tailored to reflect the power company's design and construction process. A copy of the survey questionnaire is provided in the Appendix. The questionnaire was e-mailed to the PM who distributed it to select personnel involved in project design, construction, and the DfS program.

The researchers traveled to the main design office to conduct interviews. A total of 21 people were interviewed. Each interview lasted approximately 30-45 minutes and some were done with both interviewers present. All of those interviewed work for the power company in design, construction, or management positions. Employees in the following positions were interviewed: Design Manager, Project Manager, Project Engineer, Mechanical designers (2), Electrical designers (2), Electrical Design Supervisor, Civil designers (2), Construction discipline leads (4), Instrumentation and Controls (I&C) designers (2), Project Safety (3), and Concrete and Site Engineering (2).

Appendix 8: Energy Company Research Methods Details

Description of project or group interviewed
This project was chosen to be a case study after a design engineer from an engineering group in a publicly traded energy company was tasked by his supervisor with researching the DfCS concept. The group focuses on designing steel and concrete structures, often associated with offshore platforms. Rather than performing design themselves, the engineers are responsible for overseeing the engineering designs completed by large engineering companies. The engineer found and reviewed the www.designforconstructionsafety.org website and called the website host to request a presentation on DfCS in his office. After several conversations, the researchers agreed to give a presentation on the topic at the office in exchange for the opportunity for project personnel to voluntarily participate in an anonymous survey and/or to be interviewed the day before the presentation.

Documents reviewed
The researchers received from their case study contact a Human Factors Constructability checklist (see appendix) that "helps to define a risk level, identify the stage of the project in which the hazard can occur, any comments/assumptions about the hazard, and also who will address it and when." This checklist includes items relating to material management, construction planning, plant layout, civil, structural, architectural, piping, mechanical, electrical and instrumentation/controls. A review by a researcher of the approximately 350 items on the list indicated 38 items that were DfCS-related.

Interview process
The researchers' contact arranged for ten interviews to occur in the engineering group's offices located in a major city in southern Midwest. Interviewees had received an email alerting them that a researcher would be on site conducting interviews. Handwritten notes were made on the interview script, under each question that was posed. Each interview typically took approximately thirty minutes. Not all questions were asked for many interviewees because the 30-minute session ended and the next interviewee was waiting at the door. The handwritten notes were later typed up by the interviewer and compiled into a document that provided all of the answers provided by the set of interviewees for each question.

Characteristics of sample interviewed: Number, disciplines, how identified/arranged
As mentioned above, the researchers' contact arranged for all of the interviews. The sample could be considered a quota sample in that the contact sought to have the sample include "a variety of experience from (5 to 35 years) and disciplines (Geotech, Civil, Structural, Arctic)" (which represent all engineering disciplines within the organizational unit) and that the individuals who ended being interviewed were those were available on the day that the interviewer were present and during a timeslot that had not already been scheduled. Based on the attitudes expressed during the interviews, it appears there was no systemic bias towards lining up interviewees who were predisposed for or against the DfCS concept.

Copy of interview script or description of how varied from generic script
A copy of the interview script is included in the appendix. It was identical to the one used for the power generator case study.

How survey conducted
All of the approximately 45 engineers within the researchers' contact's engineering group received an email from the contact alerting them that the researchers would be conducting interviews and making a presentation on the Safety by Design concept (the term preferred by the contact over the term Designing for Construction Safety) and requesting them to complete an anonymous online survey before the researchers arrived. The survey was administered using surveymonkey.com.

Copy of survey
A copy of the survey is provided in the appendix.

Characteristics of survey sample
Thirty-four engineers completed the survey. Because the survey is anonymous and no demographic data were collected, it is not known whether the respondents differed in terms of engineering discipline, years of experience or whether they were scheduled to be interviewed.

Appendix 9: Industry Survey Questionnaire

Design for Construction Safety Survey of Owners and Developers

Researchers at Bucknell University and Oregon State University are conducting academic research on Design for Construction Safety (DfCS). DfCS is a process in which architects and engineers (A/Es) explicitly consider the safety and health of **construction workers** as they make design decisions on the permanent features of the facility. Some safety professionals believe DfCS can help make construction sites safer and less unhealthy.

We would very much appreciate your sharing your views of DfCS by answering the questions below. We anticipate the survey will take you approximately 15 minutes to complete. Your answers will be kept confidential; the data will be used only for aggregated statistical analysis and will not be released outside of the research team. If you have any questions or concerns, please do not hesitate to ask. Contact information for the principal investigators is provided at the end of this survey.

Thank you for taking the time to participate!

1. Had you heard of Design for Construction Safety (DfCS) before this survey? Please place a check by the statement that best reflects how you feel.

___ I had never heard of DfCS.
___ I had heard of DfCS but my organization has never considered implementing it.
___ My organization has considered implementing DfCS but has never done so.
___ My organization has been involved with DfCS on a limited basis.
___ My organization routinely ensures DfCS occurs on our projects.

2. Which statement best matches your overall attitude toward the DfCS concept?

___ The potential benefits of DfCS do not seem compelling to me.
___ The benefits of DfCS sound promising but there are too many barriers to try implementing it.
___ The benefits of DfCS sound like a good idea. I would consider trying it.
___ DfCS sounds like a winner. I have already or will likely try to implement it

3. If your organization formally addresses construction worker safety and health in the design of its projects, what process/resources does it use? Please check all that apply.

___ Construction worker safety is part of the architect-engineer (A/E) scope of work per their contract
___ Design checklists
___ Constructability reviews
___ In-house design guides
___ Computer program. Name of program: _____
___ Other: _____
___ No specific process/resources

4. If your organization implements DfCS on projects, how important is DfCS to construction worker safety and health compared to other safety and health programs/processes that are currently implemented? DfCS is:

___ Not at all important
___ Less important
___ About the same importance

___ More important
___ Significantly more important
___ I don't know

5. What motivates, or would motivate, your organization to implement DfCS on its projects? Please check all that apply.

___ Competitive advantage
___ Improved construction worker safety and health
___ Improved facility occupant safety and health
___ Improved quality of construction
___ Enhanced organization reputation
___ Reduced project cost
___ Shorter project schedules
___ Other: _____

6. What do you feel are the most important barriers to implementing DfCS on your organization's projects?

7. Please place a check by the statement that best reflects how you feel about whether typical contract clauses hinder the use of DfCS.

___ The language in my company's typical design and construction contracts explicitly rejects the idea of A/Es having anything to do with safety and this won't change.
___ It would take a lot of work, but the typical language in my company's contracts that conflicts with A/Es performing DfCS could be changed.
___ It would be easy to modify my company's typical contract language to allow A/Es to perform DfCS.
___ It would not be necessary to change my company's typical contract language to allow an A/E to perform DfCS.

8. Would you support modifications to standard A/E contract documents (i.e., those promulgated by the American Institute of Architects and the Engineers Joint Contracts Document Committee), to allow A/Es to voluntarily perform DfCS on a project while limiting their liability? Please place a check by the statement that best reflects how you feel.

___ Yes, I would support such modifications regarding DfCS.
___ Yes, I would support modifications regarding DfCS if they did not impact other aspects of the A/E's role and responsibilities on a project.
___ Yes, I would support modifications regarding DfCS if they did not impact my organization's roles and responsibilities on a project.
___ No, I would not support modifications to the standard contract documents.
___ I am not familiar with the standard contract documents.

9. Please place a check by the statement that best reflects how you feel about potential A/E resistance as a barrier to DfCS.

___ A/Es will never agree to perform DfCS and my organization cannot force them to do it.
___ A/Es will resist, but my organization can insist the A/Es we hire perform DfCS.
___ Some A/Es my organization uses will agree to perform DfCS while others will not.
___ Most of the A/Es my organization uses will gladly perform DfCS.

10. Please place a check by the statement that best reflects how you feel about whether A/Es are capable of performing DfCS.

___ Most A/Es could never learn enough to effectively perform DfCS.

___ It would take a lot of effort, but most A/Es could learn enough to effectively perform DfCS.
___ Most A/Es could perform DfCS with assistance from others, e.g., Construction Managers and contractors.
___ Most A/Es could easily learn enough to effectively perform DfCS.
___ Most A/Es are already capable of effectively performing DfCS.

11. If I was reasonably confident that DfCS would reduce my total **project** costs (design and construction) by 2%, I would be willing to pay A/Es up to _____% more in **design** fees to perform DfCS. (please enter a percentage)

12. Please place a check by the statement that best reflects how you feel about whether potential increases in A/E fees are a barrier to DfCS in the industry.
___ A/Es would need to increase their fees so much to perform DfCS that it will never happen.
___ It would take a lot of work, but the higher design fees associated with A/Es performing DfCS could become acceptable.
___ The increased design fees associated with DfCS could be justified to higher management.
___ A/Es would not need to increase their fees and/or the modest increases would not be a problem at all.

13. Please place a check by the statement that best reflects your concerns about your organization's liability with respect to DfCS.
___ I believe that addressing construction worker safety during design is likely to <u>increase</u> my organization's liability exposure.
___ I believe that whether or not construction worker safety is addressed during design <u>will not affect</u> my organization's liability exposure
___ I believe that addressing construction worker safety during design is likely to <u>decrease</u> my organization's liability exposure.

14. If your organization considered DfCS but decided not to implement it, what were the reasons for not implementing it? Please select all that apply.
___ Not applicable to my organization
___ Too costly
___ Added design duration
___ No perceived benefit to my organization
___ Not enough information or knowledge about DfCS
___ Other project objectives had higher priority
___ Other: _____

15. What priority does your organization place on the following criteria with respect to its construction projects? Please rank the criteria with 1 being the highest priority, 2 the second highest priority, and so forth.
___ Aesthetics
___ Construction worker safety and health
___ Facility user safety and health
___ Maintenance worker safety and health
___ Project cost
___ Project schedule
___ Quality of the final product
___ Other: _____

16. If a substantial portion of the industry elected to perform DfCS on projects, how ***might*** the following items change? Please check one box in each row.

	Decrease	No Change	Increase	I don't know
Construction injuries				
Design costs				
Construction costs				
Total project costs to the owner				
Design durations				
Construction durations				
Total design and construction durations				
Construction quality				
The number of lawsuits against owners				
The number of lawsuits against A/Es				
The reputation of A/Es within society				
Other:				

17. What changes to your organization's structure and/or project development process were made, or would be needed, in order to implement DfCS on projects?

18. What would enable or assist your organization in implementing DfCS on your organization's projects?

Thank you for sharing your opinions with us. It is now very important to our research that we know a few things about you and your organization. As stated earlier, your answers will be kept confidential and used only for aggregated statistical analysis.

19. The category that best fits my organization is:
___ Owner
___ Developer
___ Designer
___ Design/Builder
___ Construction Manager
___ Contractor
___ Other: _____

20. Which of the following activities does your organization perform using your own employees? Please select all that apply.
___ Site civil and/or geotechnical engineering
___ Structural engineering
___ Mechanical systems engineering
___ Construction
___ Construction Management
___ Other: _____

21. The approximate percentage of my organization's construction projects associated with each market segment is: (please write in two numbers that add to 100)
_____% Public sector
_____% Private sector

22. My organization has approximately _____ employees.

23. The approximate percentage of my organization's construction projects associated with each market segment is: (please write in four numbers that add to 100)

_____% Commercial
_____% Industrial
_____% Infrastructure/heavy civil
_____% Residential

24. Approximately what percentage of your organization's projects use the design-build method of project delivery? ____%

25. Approximately what percentage of your organization's projects is constructed by your organization's own employees? ____%

26. Where are your organization's facilities located? Please select all that apply.

___ Northeast U.S.	___ Mountain states	___ Midwest U.S.
___ Mid-Atlantic U.S	___ Southwest U.S.	___ Europe
___ Southeast U.S.	___ West Coast	___ Asia

Thank you again for helping us to improve construction safety by participating in this survey!

If you have any question or comments, please contact us anytime:
Prof. Mike Toole, Bucknell University, mike.toole@bucknell.edu, 570-577-3820
Prof. John Gambatese, Oregon State University, john.gambatese@oregonstate.edu, 541-737-8913

Appendix 10: Sample Survey Distribution E-mail

Dear _____:

Researchers at Bucknell University and Oregon State University are conducting a research study titled "Owners Role in Facilitating Designing for Construction Safety." The research, which is funded by the National Institute for Occupational Safety and Health (NIOSH) and the Center for Construction Research and Training, aims to investigate the role that owners and developers of capital projects can play in promoting designing for construction safety (DfCS) on their projects. DfCS is a process in which architects and engineers (A/Es) explicitly consider the safety and health of construction workers as they make design decisions on the permanent features of the facility. The results of the study will be used to develop several practical resources including a "How to Guide" for use by owners/developers to assist them in having their projects designed for safety during construction.

Part of the research study involves surveying owners and developers across the U.S. regarding their attitudes towards and experiences with designing for construction safety. We would like to get the input of CURT members as they represent an important segment of the owner/developer community and are contacting you to ask for your assistance in distributing the survey to your membership. You can view the survey questionnaire by opening the attached Word document or at the following link: http://www.surveymonkey.com/s/WXF67NY. The survey link could be sent out via an e-mail listserv, a periodic newsletter, or other means in which you communicate with your membership. If you are not the appropriate person to contact regarding this request, is there someone else within CURT who we should contact about sending out the survey?

We would very much appreciate your help with the study and will gladly share the results of the survey with your members. If you have any questions about the study, please contact me or Dr. John Gambatese at Oregon State University, john.gambatese@oregonstate.edu.

Sincerely,

Mike Toole and John Gambatese

Appendix 11: Hospital Project Case Study Survey Data

Hospital Project Design for Construction Safety

Had you heard of Design for Construction Safety (DfCS) before this survey?

Answer Options	Response Percent	Response Count
I had never heard of DfCS.	65.4%	17
I had heard of DfCS but my organization has never considered implementing it.	15.4%	4
My organization has considered implementing DfCS but has never done so.	7.7%	2
My organization has been involved with DfCS on a limited basis.	3.8%	1
My organization routinely ensures DfCS occurs on our projects.	7.7%	2
answered question		26
skipped question		0

2

Which statement best matches your overall attitude toward the DfCS concept?

Answer Options	Response Percent	Response Count
The potential benefits of DfCS do not seem compelling to me.	11.5%	3
The benefits of DfCS sound promising but there are too many barriers to try implementing it.	3.8%	1
The benefits of DfCS sound like a good idea. I would consider trying it.	50.0%	13
DfCS sounds like a winner. I have already or will likely try to implement it	34.6%	9
answered question		26
skipped question		0

3

If your organization formally addresses construction worker safety and health in the design of its projects, what process/resources does it use? Please check all that apply.

Answer Options	Response Percent	Response Count
Construction worker safety is part of the architect-engineer (A/E) scope of work per their contract	16.0%	4
Design checklists	28.0%	7
Constructability reviews	64.0%	16
In-house design guides	32.0%	8
Computer program	4.0%	1
No specific process/resources	20.0%	5
Other (please specify)	24.0%	6
answered question		25
skipped question		1

Number	Response Date	Other (please specify)
1		OSHA design guidelines & OSHA Fall Protection design guidelines
2		LEED and fundamental sustainability concepts
3		Operational level hazard analysis
4		We don't provide design services
5		I am not aware of/ familiar with a formal construction worker safety policy/ procedures implemented in my company
6		We use an integrated project design approach where all CM/GCs and trade partners work alongside the designers from project inception.

4

If your organization implements DfCS on projects, how important is DfCS to construction worker safety and health compared to other safety and health programs/processes that are currently implemented? DfCS is:

Answer Options	Response Percent	Response Count
Not at all important	0.0%	0
Less important	9.1%	2
About the same importance	22.7%	5
More important	18.2%	4
Significantly more important	0.0%	0
I don't know	50.0%	11
answered question		22
skipped question		4

5

What motivates, or would motivate, your organization to implement DfCS on its projects? Please check all that apply.

Answer Options	Response Percent	Response Count
Competitive advantage	50.0%	13
Improved construction worker safety and health	84.6%	22
Improved facility occupant safety and health	65.4%	17
Improved quality of construction	84.6%	22
Enhanced organization reputation	57.7%	15
Reduced project cost	69.2%	18
Shorter project schedules	50.0%	13
Other (please specify)	11.5%	3
answered question		26
skipped question		0

Number	Other (please specify)
1	designers need to be compensated for taking on more scope and liability. contractors & designers work as a team and be equally responsible for DfCs. keep the lawyers out in this process!!!
2	lower WC Insurance rates for my company
3	i don't know

6

Please place a check by the statement that best reflects how you feel about whether typical contract clauses hinder the use of DfCS.

Answer Options	Response Percent	Response Count
The language in my company's typical design and construction contracts explicitly rejects the idea	23.8%	5
It would take a lot of work, but the typical language in my company's contracts that conflicts with	19.0%	4
It would be easy to modify my company's typical contract language to allow AEs to perform DfCS.	33.3%	7
It would not be necessary to change my company's typical contract language to allow an AE to	23.8%	5
answered question		21
skipped question		5

7

Would you support modifications to standard AE contract documents (i.e., those promulgated by the American Institute of Architects and the Engineers Joint Contracts Document Committee), to allow AEs to voluntarily perform DfCS on a project while limiting their liability?

Answer Options	Response Percent	Response Count
Yes, I would support any modifications regarding DfCS.	38.5%	10
Yes, I would support modifications regarding DfCS if they did not impact other aspects of the AE's	30.8%	8
Yes, I would support modifications regarding DfCS if they did not impact my organization's roles	7.7%	2
No, I would not support modifications to the standard contract documents.	11.5%	3
I am not familiar with the standard contract documents.	11.5%	3
answered question		26
skipped question		0

8

Please place a check by the statement that best reflects how you feel about potential AE resistance a barrier to DfCS.

Answer Options	Response Percent	Response Count
A/Es will never agree to perform DfCS and my organization cannot force them to do it.	12.5%	3
A/Es will resist, but my organization can insist the A/Es we work with perform DfCS.	20.8%	5
Some A/Es my organization works with will agree to perform DfCS while others will not.	54.2%	13
Most of the A/Es my organization works with will gladly perform DfCS.	12.5%	3
answered question		24
skipped question		2

9

Please place a check by the statement that best reflects how you feel about whether AEs are capable of performing DfCS.

Answer Options	Response Percent	Response Count
Most AEs could never learn enough to effectively perform DfCS.	3.8%	1
It would take a lot of effort, but most AEs could learn enough to effectively perform DfCS.	23.1%	6
Most AEs could perform DfCS with assistance from others, e.g., construction managers and	57.7%	15
Most AEs could easily learn enough to effectively perform DfCS.	11.5%	3
Most AEs are already capable of effectively performing DfCS.	3.8%	1
answered question		26
skipped question		0

10

If a typical owner was reasonably confident that DfCS would reduce total project costs (design and construction) by 2%, he or she would likely be willing to pay A/Es up to _____% more in design fees to perform DfCS. (please enter a percentage)

Answer Options	Response Count
	22
answered question	22
skipped question	4

Number	Response Date	Response Text
1		20
2		30
3		0
4		??
5		0.1
6		0
7		2
8		10
9		5
10		0
11		2
12		15
13		0
14		0.5
15		2
16		??
17		1
18		?
19		5
20		0.5
21		15
22		0
11		6

Please place a check by the statement that best reflects how you feel about whether potential increases in AE fees are a barrier to DfCS in the industry.

Answer Options	Response Percent	Response Count
AEs would need to increase their fees so much to perform DfCS that it will never happen.	4.0%	1
It would take a lot of work, but the higher design fees associated with AEs performing DfCS could	32.0%	8
The increased design fees associated with DfCS could be justified to higher management.	28.0%	7
AEs would not need to increase their fees and/or the modest increases would not be a problem at	36.0%	9
answered question		25
skipped question		1

12

Please place a check by the statement that best reflects your concerns about your organization's liability with respect to DfCS.

Answer Options	Response Percent	Response Count
I believe that addressing construction worker safety during design is likely to increase my	30.8%	8
I believe that whether or not construction worker safety is addressed during design will not affect	11.5%	3
I believe that addressing construction worker safety during design is likely to decrease my	57.7%	15
answered question		26
skipped question		0

13

If your organization considered DfCS but decided not to implement it, what were the reasons for not implementing it? Please select all that apply.

Answer Options	Response Percent	Response Count
Not applicable to my organization	47.6%	10
Too costly	4.8%	1
Added design duration	0.0%	0
No perceived benefit to my organization	4.8%	1
Not enough information or knowledge about DfCS	47.6%	10
Other project objectives had higher priority	4.8%	1
Other (please specify)	4.8%	1
answered question		21
skipped question		5

14

What priority does your organization place on the following criteria with respect to its construction projects? Please rank the criteria with 1 being the highest priority, 2 the second highest priority, and so forth.

Answer Options	#1 priority	#2 priority	#3 priority	#4 priority	#5 priority	#6 priority	#7 priority	Rating Average	Response Count
Aesthetics	0	2	2	3	4	3	9	5.35	23
Construction worker safety and health	6	2	1	2	3	1	6	4.00	21
Facility user safety and health	3	3	2	1	7	4	1	4.05	21
Maintenance worker safety and health	1	1	2	2	0	9	4	5.21	19
Project cost	2	7	5	5	1	0	1	3.00	21
Project schedule	0	4	7	4	4	2	0	3.67	21
Quality of the work	10	3	2	4	2	2	0	2.61	23
Other (please specify rank and criterion)									2
answered question									24
skipped question									2

Number	Response Date	Other (please specify rank and
1	Aug 4, 2009 10:27 PM	I cannot answer this unanchored question in its current format.
2	Aug 12, 2009 6:03 PM	#1 functionality of the completed project for the end users

15

If a substantial portion of the industry elected to perform DfCS on projects, how might the following items change? Please check one box in each row.

Answer Options	Decrease	No Change	Increase	I don't know	Response Count
Construction worker injuries	23	2	0	0	25
Design costs	0	6	16	3	25
Construction costs	10	7	7	1	25
Total project costs to the owner	7	10	7	1	25
Design durations	0	13	11	0	24
Construction durations	9	14	1	1	25
Total design and construction durations	7	11	7	0	25
Construction quality	2	5	18	0	25
The number of lawsuits against owners	21	3	0	1	25
The number of lawsuits against AEs	15	5	3	2	25
The reputation of AEs within society	1	7	15	2	25
answered question					25
skipped question					1

16

The category that best fits my organization is:

Answer Options	Response Percent	Response Count
Owner	8.3%	2
Designer (Architect or Engineer)	33.3%	8
Design/Builder	20.8%	5
GC/CM	20.8%	5
Trade Contractor	8.3%	2
Other (please specify)	8.3%	2
answered question		24
skipped question		2

Number	Response Date	Other (please specify)
1	Aug 4, 2009 6:07 PM	All of the above less Owner.
2	Aug 10, 2009 5:00 AM	GC
17		

Number	Response Date	% Public sector	% Private sector
1		30	70
2			100
3		50	50
4		50	50
5		40	60
6		50	50
7		25	75
8		40	60
9		25	75
10		25	75
11		10	90
12		30	70
13		70	30
14		50	50
15		30	70
16		40	60
17			100
18		40	60
19		20	80
20		40	60
21		50	50
22		25	75
23		30	70
24			100
18			

Which of the following activities does your organization perform using your own employees? Please select all that apply.

Answer Options	Response Percent	Response Count
Site civil and/or geotechnical engineering	4.8%	1
Structural engineering	28.6%	6
Mechanical systems engineering	23.8%	5
Construction	61.9%	13
Construction Management	61.9%	13
Other (please specify)	23.8%	5
answered question		21
skipped question		5

Number	Response Date	Other (please specify)
1		carpentry
2		Manufacturing
3		Architectural Design
4		Architecture
5		Architectural Design
19		

My organization has approximately ____ employees.

Answer Options	Response Count
	23
answered question	23
skipped question	3

Number	Response Date	Response Text
1		100
2		100
3		10
4		110
5		700
6		800
7		150
8		800
9		250
10		150
11		300
12		200
13		150
14		600
15		900
16		300
17		3000
18		300
19		400
20		800
21		800
22		2000
23		43000
20		

The approximate percentage of my organization's construction projects associated with each market segment is: (please write in four numbers that add to 100)

Answer Options	Response Percent	Response Count
% Commercial	100.0%	23
% Industrial	69.6%	16
% Infrastructure/heavy civil	56.5%	13
% Residential	73.9%	17
answered question		23
skipped question		3

Number	Response Date	% Commercial	% Industrial	% Infrastructure/heavy civil	% Residential
1		60	10	0	30
2		100	0	0	0
3		93	5	1	1
4		85	5	0	10
5		80	10	5	5
6		70	20		10
7		75			25
8		100			
9		60	40	0	0
10		100	0	0	0
11		50	50		
12		60			40
13		100			
14		100			
15		90	10	0	0
16		100	0	0	0
17		100			0
18		20	18	60	2
19		40	40	10	10
20		75	25		
21		75	25	0	0
22		10	0	0	5
23		100			
21					

Approximately what percentage of your organization's projects use some type of integrated project delivery (IPD) approach, such as design-build or CM at Risk?

Answer Options	Response Count 23
answered question	23
skipped question	3

Number	Response Date	Response Text
1		40
2		25
3		50
4		60
5		2
6		10
7		75
8		30
9		25
10		25
11		90
12		75
13		75
14		60
15		10
16		20
17		80
18		5
19		40
20		5
21		20
22		10
23		80
22		40

Approximately what percentage of your organization's projects is constructed by your organization's own employees?

Answer Options	Response Count 24
answered question	24
skipped question	2

Number	Response Date	Response Text
1		10

2	90
3	0
4	100
5	0
6	0
7	15
8	0
9	50
10	0
11	10
12	90
13	25
14	100
15	0
16	20
17	0
18	100%
19	20
20	0
21	0
22	100
23	0
24	0
23	

Where are your organization's facilities located? Please select all that apply.

Answer Options	Response Percent	Response Count
Northeast U.S.	29.2%	7
Mountain states	16.7%	4
Midwest U.S.	37.5%	9
Mid-Atlantic U.S	37.5%	9
Southwest U.S.	29.2%	7
Europe	0.0%	0
Southeast U.S.	12.5%	3
West Coast	87.5%	21
Caribbean	0.0%	0
South America	0.0%	0
Asia	0.0%	0
Middle East and Africa	0.0%	0
answered question		24
skipped question		2

Appendix 12: Hospital Project Case Study Interview Compilation

Drivers

Who is the primary driver of DfCS on this project?

(Design engineer) No primary driver known. Not modifying design specifically for safety; not tasked to do so.

(CM/GC) CM/GC firm. No clear lines; all involved.

(CM/GC) Safety is not on minds of architects and engineers now. Safety will be considered by trades during shop drawing phase.

(CM/GC) Trade partners. Safety is part of good design, but we don't have safety checklists, although we would like them.

(Architect) When completing preliminary survey, couldn't figure out what DfCS had to do with me. Construction is the primary driver. DfCS not explicitly communicated by owner or CM/GC.

(Architect) Contractors. No owner-specific communication of DfCS; more indirect through IPD.

(Architect) Trade partners. Never heard aout DfCS until survey last week. He is a medical space planner. The survey didn't seem applicable to architects. Safety considerations is implied only. Example of his CBAs: ease of installation does not equal safety of installation.

(lead technical coordinator for architect) This may be the same as what John wrote for "Architect" because I may have come in late and perhaps also left early.

(Architect) In CA, architects should think about construction safety during design because OSHPOD (regs for hospitals) may require change orders later. Hospitals are special buildings in CA. Safety of users and occupants govern, mostly from a seismic design perspective.

(Owner) Sutter Health primary driver of IPD. Construction trades driver of safety. No owner communication on safety.

(Owner) Trade partners. Also, GC/CM.(Owner) Owner insisted on IPD because they were sick and tired of old system with post-project litigation. The CM and trade partners are equally focusing on getting safety considered during design.

(Concrete contractor) Trade partners

(Drywall subcontractor) Subcontractors are the primary driver. Not aware of any specific communication from the owner regarding DfCS. A/Es more reactive in their designs.

(Owner) Subcontractors and CM/GC

(Owner) I am not close enough to design to know. I mostly know about operations safety and health. Expects CM/GC and trade contractors to bring in construction safety.

(Electrical contractor) Safety is very big at (interviewee firm name). (name of designer) designs per NEC, but safety enhanced because IPD allows feedback. Safety issues are raised naturally.

(MEP contractor) DfCS is happening because trades are driving it.

(GC --not CM): Trade partners. Owner is not driver.

(Steel sub and concrete sub) Steel safety manager is not yet part of project, but will be. But interviewee can tell structural engineer their preferences for safe design. While designers are not explicitly looking at safety checklists, they are open to trade partners' input, which includes safety. Example: opening in floor. Trade partners are always thinking about safety.

What do you think is their primary motivation for pursuing DfCS?

(Design engineer) Safety rating – EMR. Asked of trade contractors.

(CM/GC) Construction is the driver. IPD facilitates DfCS.

(CM/GC) Owner values: functioning building and user safety.

(CM/GC) Safety is part of (constructability). When asked if design can handle construction loads, he responded they discussed beefing up slab for this reason 2 hours ago.

(Architect) Safety is implied; part of the process but not formal.

(Architect) Efficiency of construction. Constructability.

(Owner) Avoiding rework; improved production; improved safety.

(Concrete contractor) Cost savings – prep ahead of time.

(Drywall subcontractor) Safety of workers; meeting OSHA requirements

(Owner) Safety and good business. It is their personal mindset to improve.

(Owner) Reduce risk.

(Owner) Safety is personal in that friends can get hurt and it makes good business sense (lower EMR).

(MEP contractor) Making money is important. Safety not often spoken but in back of mind and drives input. Unrealistic schedules are safety issues.

(GC) Cost savings, especially on this project. Biggest hurdle on this project is that everyone has own insurance. OCIP would get you ¾ way there. You need project-specific E&O and WC insurance. (interviewee firm) is not stamping drawings but they are influencing design and are design-builders.

(Owner) Avoid rework. Make safer. Example: formsavers cost more upfront but save $ over all.

What is your primary motivation for participating in DfCS?

(Design engineer) Not doing DfCS on project. His contract clearly states no responsibility for safety. He wouldn't know how to do it because he is in a vacuum. Target savings is driving project. What is easier to erect is probably safer. He is teaching his engineers to ask "How would you rather do it?" He is motivated to do this because 25% of his firm's profits on this project depend on whether the project target cost is met, which has caused a change in the mindset of engineers and made them willing to listen to contractors.

(CM/GC) Participate in OCIP savings. Incentive: 25% of profit tied to project performance as part of IPD contract.

(Owner) No involvement in any safety.

(Concrete contractor) Cost savings; safety

(Architect) To help meet contractor needs. Control costs. No RFIs.

(Architect) They have to be more conscious of safety (single digit % concerns) to prevent changer orders and RFIs.

(MEP contractor) Easier and faster is safer and less expensive.

(GC) They are hoping E&O never kicks in. Safety is interviewee firm's first responsibility. Driven into culture.

(Owner) Not participating. He attends cluster meetings. If occupant safety comes up, architect would handle it. He is running several projects so he doesn't have time to get involved in detailed decisions.

(Owner) She started working at Clorox, which is a very safety conscious company. Her husband is an electrician.

(Steel sub and concrete sub) Steel sub is self-insured but life safety does not need $ consideration. With concrete, more time upfront saves money downstream. Projects run smoother because no injury shutdowns and costs associated with injuries are less. Productivity is hurt when hazards are present.

Would DfCS have been implemented if the primary driver was not interested in it?

(Design engineer) No. Typical standards/details are not questioned on most projects. If a safer detail identified, it may or may not get passed on to future projects, depending on the principal involved. (He drew sketch of detail where beam could be more easily swung into place.)

(Architect) Depends on project.

(Architect) Little difference.

(Architect) Depends on client (client driven) or firm culture.

(Architect) No. No access to knowledge.

(CM/GC) Yes, construction sequencing. No, design checked after it is completed to work during construction.

(Owner) No; no coordination up front.

(Owner) Safety wouldn't be considered without IPD.

(Concrete contractor) No.

(Drywall subcontractor) Yes, they would push it, but it would be dependent on the owner.

(Owner) No. Save time and money using IPD.

(MEP contractor) No.

(GC) Owners and architects have not bought into safety as #1. Nothing would have changed from industry standard process if the GC and trades hadn't pushed for safety.

(Steel sub and concrete sub) The owner role is to ensure collaboration. They manage the forrest so the trades can manage the trees.

Processes

What did the owner do initially to initiate and enable DfCS?

(Architect) Nothing specific; just implemented IPD.

(Architect) When asked hypothetically if he would consider safety: He would need help: specific criteria, education, process tools like CBA, balance between safety and other criteria.

(Concrete contractor) Implemented IPD.

(Owner) Use A3 process to select trade contractors and safety as part of the contracting process.(Owner) Not involved in individual decisions. They let AE and contractors run process. They just focus on target costs and push entities to meet them.

(CM/GC) Only time we have explicitly altered design for safety was adding bolted up I beam at large floor opening.

How do DfCS opportunities get identified?

(Architect) Input from erectors/builders. Review of drawings and questioning how the work will be performed (e.g., moving MRI equipment through the building).

(Architect) Reviewing model (projected) for cost, quality, etc. Safety comes up. Heavy medical equipment needs to be analyzed for how it will be moved into place.

(Owner) Not just implementing as usual. Asking question: How can we do it better?

(Concrete contractor) Not leading off meetings with safety; comes up in option analysis.

(Owner) Facility Engineering (end-user) is relied upon to collaborate with the project team.

(Electrical contractor) (names of interviewees) wrote white paper to owner to make sure they understand proper facility maintenance. Each floor has 12KV, not 480V as usual. Safety is in background.

(MEP contractor) Trades identify it and AEs listen. Prefab is a big opportunity for HVAC and plumbing. 40' section of shaft duct being dropped by tower crane.

(GC) I don't know if we have really identified safety opportunities on this project. It hasn't come up in cluster meetings. (CM) might feel otherwise. (Interviewee stated his attendance at cluster meetings has waned due to other meetings.)

(Owner) He doesn't remember specific instances of safety only governing. But he remembers discussions about prefabbing piping including safety as well as speed, lack of clutter. Ditto for crane pick points. He just listens.

(Owner) Everyone thinks about constructability. Safety is just one aspect of this. She can't think of any specific construction safety situations because she focuses mostly on user safety.

(CM/GC) Constructability reviews are occurring. Example: (individual) from drywall sub is reviewing floor plans for drywall installation. Also, plumbing layout being reviewed by plumber. Focus is on cost savings.

(CM/GC) As part of standard design review.

(Steel sub and concrete sub) Informal interactions. The structural engineer is two doors down and completely accessible. Drawing dumps sometimes occur and people rush to review. But some details just get shared then informal interaction occurs. SE doesn't reject or push back.

(Drywall): We say to the AE, "This is how we would do this.' Safety is implicit.

How are DfCS design decisions made? Who makes them and how are meetings, emails or phone conversations used?

(Design engineer) Informal process. Changes/interaction made periodically. Go ask the contractor down the hall if there is a question. No checklist used.

(CM/GC) Doing DfCS subconsciously. No specific safety exercise. Safety is a byproduct of good design.

(CM/GC) Through the Choosing by Advantages (CBA) process – safety is included.

(CM/GC) He only attends interiors cluster meetings. Recalls discussions about prefab bathroom modules. Safety had advantages but need to rall team and window is closing. He is investigating past use, union jurisdiction issues, structural engineering issues, architectural challenges, labor productivity concerns, waterproofing details.

(CM/GC) Email, meetings, CBA forms. Example: safety was a big issue in decision not to use modular bathrooms. The risk of dropping a heavy unit outweighed other safety advantages. Line of site and disruption of sequencing also factors.

(Concrete contractor) Discussions of design in cluster meetings.

(Architect) No safety in CBAs. Safety has not been a factor in decisions. Constructability reviews.

(Architect) If I was supposed to think about safety and I knew about specific opportunities, of course I would do it. It is the right thing to do.

(Architect) All construction folks knew about safety associated with panels but (interviewee) wasn't aware until told. Email and F2F.

(Drywall subcontractor) Very informal process, except for A3's and CBAs.

(Owner) A3 process

(Owner) A3 process and CBA process. CBA process can be "gamed"; some validation of results is needed (e.g., put results in front of another group for analysis and validation).

(Owner) Large firms come in with good safety records and low mod rates and practices to achieve this. They do not want to change these good practices. Designers are always asking "how can we do this better?"

Construction worker safety is included in the Env. Impact Report, which she has been involved in from a construction planning perspective. Examples include noise, release of contaminants. Contingency plan documents are also relevant.

(Electrical contractor) (name of designer) includes disconnect at each piece per Cal. Electrical code, which helps during construction.

(lead technical coordinator for architect) Most of what we have heard and changed has changed process (now it is done; how we implement the looks) but not how it looks. Example: parapet wall.

(MEP contractor) Cluster meetings. Emails may not include direct safety references but underlying discussions. Trades would not hesitate to raise safety only issue and owner would listen.

(GC) BIM forces conversations about things coming together. Example: steel sub asked the structural engineer to use a detail that allows prefabrication and/or make easier and safer. Interviewee firm does same on lesser scale, such as using viscous wall dampeners. But mostly focused on cost and speed, which are tied to safety.

(Steel sub and concrete sub) If other trade are potentially affected, they are cc:d on email. Also, structural cluster meetings each week give opportunity for special issues to be discussed. Answers to previous question apply here. Buzzsaw (drawing and other electronic document repository that includes an email alert when new document has been uploaded) and Last Planner software used.

What is the form and content of DfCS information that is communicated?

(Design engineer) E-mail of detail or question, followed by phone call or conversation.

(Architect) Face-to-face, and e-mail.

(Architect) BIM makes traditional understanding of design stages irrelevant. Models are not CD stage, but enough to allow trade partners to do their own DD models. This helps not locking in trade partners in too narrow a design.

(Concrete contractor) Concept: Last Planner. Detail: e-mail.

(Electrical contractor) (name of interviewee) talks with HB about sequencing to make his process safer. Designers just indicate rough routing; trades choose exact location based on many factors.

(lead technical coordinator for architect) CBAs he has seen have never involved safety. Safety is a by-product of constructability. This is ongoing. Cluster meetings are just points in time. Ad hoc, spontaneous F2F discussions (allowed by co-location) are ongoing. Iterative loops. Constructability feedback is meaningful. Trades are not just reactive.

(GC) Safety is tracked in Last Planner (meeting minutes, 6 and 3 week look aheads), emails.

(Owner) There is a lot of process here. When someone has an idea, an A3 and CBA used to analyze big decisions. We move fast. Lots of F2F because faster than email.

(Owner) She assumes safety is considered in the A3 proces, such as for tower crane decisions.

(Steel sub and concrete sub) Mentioned project card.

What phases of construction have had stronger DfCS consideration? Why?

(Design engineer) More consideration of DfCS now as part of construction documents phase.

(Architect) No difference. IPD/BIM change design process.

(Architect) Most input in construction documents phase.

(Architect) Safety explicitly discussed during design of panel system but he guesses steel and concrete also given safety consideration.

(Owner) Good results in all phases.

(Owner) All phases have benefitted equally.

(Owner) Not sure, but aware of curtainwall panels receiving a lot of safety attention.

(Concrete contractor) Stronger in structural because it is farther along (easier if there is more detail).

(Drywall subcontractor) Easier in design. Can get DfCS in easier in the design phase.

(Owner) Careful planning for glass and glazing; window washing.

(Electrical contractor) Codes now include proper clearances for installation and maintenance. Example: Fixture on glass dome on other project forced (name of interviewee firm) to hire a theatrical lighting firm.

(GC) Structural has received more safety attention because further along.

(CM/GC) I just haven't heard people say 'How can we do this safer?' It wouldn't be a tough conversation to have.

(CM/GC) Demolition and abatement plan got a lot of attention. Structural stuff has received more attention. Pipe prefab: mechanical trades told AE what to add to allow prefab.

(Steel sub and concrete sub) They are not aware of how safety managed in other clusters. GC/CM Super, who attends most cluster meetings, occasionally finds something they didn't think about.

What DfCS-related information was initially possessed by each of the following entities? What about now?

Owner

(Design engineer) None

(Architect) No info

(Architect) None

(Architect) Owner doesn't bring safety knowledge because they typically don't have enough field expertise.

(Owner) None

(Owner) None.

(Owner) She personally has safety knowledge to help implement DfCS.

(Concrete contractor) Not in detailed discussions.

(Drywall subcontractor) None

(Owner) Yes, could make decision to design for safety if needed.

(Owner) Hospital staff for O&M safety.

(Electrical contractor) Constructability discussions occurring at cluster meetings and documented in minutes. Also, lots of ad hoc F2F discussions. Owner comes to cluster meetings. He is high level but has detail preferences.

(GC) They are at 1,000,000 foot level. But they engage only safe firms (perhaps less so for finishes subs).

(CM/GC) No knowledge.

(CM/GC) They only provide AEs with user safety guidance.

A/E

(Design engineer) None

(Architect) Some, depending on construction experience.

(Architect) Ease of installation different than safe to install.

(Architect) No knowledge.

(Architect) Safety information possessed varies with individuals. Interviewee has a lot of project experience.

(Owner) Not much; just at the table receiving info.

(Owner) More receptors of safety information but participate in decisions. AEs are encouraged to push back on all cost escalation changes but need to justify. Example: patient handling hardware.

(Concrete contractor) Mixed: some have construction experience; mostly end-user safety. Uses trade contractor input and details.

(Drywall subcontractor) No; some recognition of influence of design on safety.

(Owner) Yes, could provide info. A/Es are experienced and have requisite knowledge.

(Owner) Don't know.

(Owner) Smithgroup has lots of field expertise. They may have people who know enough to help identify DfCS opportunities.

(Electrical contractor) Knowledgeable through code requirements.

(MEP contractor) AE was not thinking of it and not capable.

(GC) Mixed. Some have construction experience but they do not want direct hands on. 95% of their focus is user safety. They do not get into construction safety.

(CM/GC) Not sure. Does AIA have standards for safety in design?

(CM/GC) Do not have expertise in construction safety.

GC/CM

(Design engineer) All design change info

(Architect) Bring construction knowledge to design.

(Architect) Through constructability reviews.

(Owner) Yes, significant

(Concrete contractor) Logistics; planning of site.

(Drywall subcontractor) Maybe, but not aware of any.

(Owner) Yes

(Owner) Important contributor.

(Owner) Lots of information, contributions.

(Electrical contractor) (name of GC individual) knows a lot about NEC.

(MEP contractor) (GC individual) has experience and motivation to drive DfCS.

(GC) CM leads half of cluster meetings and safety does come up. (individual name) attends planning and logistics meetings.

(CM/GC) GC has good safety program, including reporting near misses. No safety meetings related to design but perhaps closer to construction they might.

(CM/GC) There are such good safety products out there that we don't need to think about safety ahead of time.

(Steel sub and concrete sub) GC/CM Super has lots of good experience.

trade partners

(Design engineer) Site safety info

(Architect) Bring construction knowledge to design.

(Architect) Through constructability reviews.

(Architect) They bring all detailed knowledge.

(CM/GC) Primary info providers.

(CM/GC) They have all the knowledge and experience so they could bring up safety issues to AE based on past experiences and ask what other options are possible.

(CM/GC) They have expertise in construction safety.

(Owner) Yes, primary

(Owner) Primary.

(Owner) Lots of information, contributions.

(CM/GC) Yes, they have the info

(Concrete contractor) Provides ideas for design changes based on their preferred/chosen detail, which is assumed to be safer. Example: Installing anchors behind the viscous wall dampers.

(Drywall subcontractor) Yes, primary contributor.

(Owner) Yes

(Electrical contractor) MEP more concerned about holes protected, soil retention.

(MEP contractor) Primary.

(GC) Primary

(Steel sub and concrete sub) Concrete interviewee was gently warned to focus more on his own trade and less on the big picture.

Barriers/Enablers/Impacts

How is safety addressed relative to other priorities such as cost, schedule, and quality?

(Design engineer) Safety of end-user top priority. No safety of construction workers specifically addressed.

(Architect) Not much formal consideration of construction safety. Holistic consideration (all types of safety).

(Architect) Safety is not explicitly considered.

(Architect) Use CBA method. Safety important to everyone. "Will take proper precautions."

(Architect) Lack of A/E knowledge of construction means and methods. Liability if A/E led; none if contractor led.

(Architect) Can't remember any conflict but safety would likely win. Core group would decide through A3 process. Everything is considered holistically.

(Owner) Examples of when it is addressed: site logistics, prefabrication, laydowns, pick points. Focus on current best practices.

(Owner) Balanced. We ask why and try to achieve same result without increasing price. Profit sharing incentives.

(Owner) Can't recall any specific examples of conflicting criteria but owner always choose safety (patient and operations) over cost.

(Concrete contractor) Safety not formally addressed. Bias based on people making the decision. Cost is not a part of the CBA process.

(Owner) No circumstances yet experience. Mostly user safety (e.g., patient lifts in rooms).

(Owner) Need to understand other side (other discipline) point of view.(Electrical contractor) Only safety issue has been user safety (high voltage, aluminum conductor).

(CM/GC) Safety would be considered as part of the A3/CBA process. Trade partner representatives are not safety managers or specialists.

(CM/GC) They use Choosing by Advantages for weighing factors, which considers value to owner and operationally effective building. A3 is used.

(Steel sub and concrete sub) Safety is always going to win, especially on this project. On other projects, his firm would walk away from project where safety wasn't #1.

What do you feel are the most important barriers to implementing DfCS on your organization's projects?

(Design engineer) Ignorance of construction site safety problems, and liability.

(Architect) Lack of architect experience regarding safety. Liability not an issue.

(Architect) Awareness/education of DfCS. Knowledge of DfCS examples. Need research to back it up. Lack of DfCS tools.

(Architect) Education, process tools. Just like sustainability. Can't this fit in with sustainability? Accredidation. Awareness.

(Architect) Lack of experience, lack of knowledge. Some people play Teflon-game.

(CM/GC) Liability; lack of stating that they are designing for safety. Non-IPD contract.

(CM/GC) Need for safety knowledge.

(CM/GC) Potential barrier would include not having safety specialist. Would need owner to say safety is paramount and needs to be included in the CBA.(CM/GC) Architect brought up liability. Archs are taught not to consider worker safety. They might do it but they do not want to admit it.

(Owner) Push-back from A/E, owner. Cost and schedule.

(Owner) We don't say no. We ask "why" five times. What is the real reason?

(Owner) No one on team would rject concept but would need guidance on how to implement in design review process. AE knowledge is OK only with experienced AEs.

(Concrete contractor) Liability (steel erector welding anchorages to steel after design complete). Lack of construction knowledge in A/Es, and lack of design knowledge in Construction personnel. Culture of industry. Specialty atmosphere.

(Drywall subcontractor) No barriers on this project. Top-down lack of focus or accountability; no enforcement mandate. Lack of collaboration.

(Owner) Rejection of the concept. How to do it is a barrier; need instructions. Lack of experience in safety and construction.

(Owner) People are too busy to consider and take care of everything.

(Electrical contractor) None.

(MEP contractor) AEs know nothing about how the field works. They are not hands-on mechanics. Designs need to change to reduce mechanical congestion, as is case in Europe. This affects prefab opportunities. Prefab bath modules are not appropriate for this building (but don't say this out loud). Architects do not get it how much workers comp insurance premiums cost.

(GC) Liability and insurance. Culture.

(Steel sub and concrete sub) Access to designers.

What changes to your organization's structure and/or project development process were made, or would be needed, in order to implement DfCS on projects?

(Design engineer) Appoint or hire a DfCS champion. Need IPD to get construction knowledge.

(Architect) Open discussion to change mindset.

(Architect) Need a process. Need a design spec; "What to design to".

(Architect) Consider safety as a factor when considering two options (CBA process).

(Architect) He is not shure whether liability would be an issue. You would think people would want us to design for safety.

(Architect) Open minds needed. Provide inexperienced architects with OSHA book. Liability is not an issue for them.

(CM/GC) Education of project team. Change in financial framework/contracts.

(CM/GC) Just as we needed education about lean, we might benefit from education about DfCS. Lean tools and processes at first sounded common sense but as you learn more, you learn nuances and value of using it. Example: value stream analysis.

(Owner) Constantly improving the process; learning as they go.

(Concrete contractor) Need project insurance. Change culture of A/Es (e.g., starting meetings with a safety topic).

(Drywall subcontractor) No changes needed to our company; already do on other projects.

(Owner) Leadership needs to be strong and effective. Need to assign responsibility for decisions.

(Steel sub and concrete sub) 90% of time they have access to structural engineer, but during shop drawing and detailing phase. Concrete sub is increasingly involved in design assist projects.

What would enable or assist your organization in implementing DfCS on your organization's projects?

(Design engineer) Need insurance buy-in.

(Architect) IPD, BIM

(Architect) Open mind; interest in safety.

(Architect) Owner promoting DfCS. IPD. Working with a CM/GC.

(Architect) Access to construction knowledge.

(Architect) They are driven by either clients' demands or the firms' mission and culture or the sense of the profession. Need guidance on what to design to.

(CM/GC) Having trade contractor expertise. Education of the project team regarding DfCS. Good tools. 4-D visualization/modeling tools.

(CM/GC) You could ask all same questions about quality. We are doing it but not explicitly. We could set up monthly meetings focusing only on DfCS. 4D modeling.

(Owner) Owner trust of trade contractors that their ideas are the best way to do it. Open communication. Proximity of team members (together). Innovation.

(CM/GC) CBA process.

(Concrete contractor) IPD. Project-specific insurance.

(Drywall subcontractor) The right culture (moral obligation or not). Open book policy on contract, across the board.

(Owner) Asking the question, "What could go wrong?"

(Steel sub and concrete sub) You get what you pay for. If trade partners are not sure they will get a project, their safety review will not be as good.

What have been, or do you foresee will be, the impacts of implementing DfCS?

(Design engineer) Change in mindset of A/Es due to IPD.

(CM/GC) Below target cost. Improved productivity and material flow. Better planning, which will lead to better safety.

(CM/GC) There are big expectations associated with IPD: productivity, no delays. Better planning leads to better safety. Will product look and feel safer? Yes. Will drawings look different/safer? Hmmm. There may be some details that will be unusual. Example: Dowels sticking up in foundation design were changed for safety reasons.

(Architect) Improved safety. Positive and negative impact to design. Positive impact on firm: reduce liability, and marketing tool. Positive to profession: improve relationship with contractors.

(Architect) No impact to aesthetics or look of building. Minimum impact to project. Cheaper. No explicit difference in the field. Yes, difference in the drawings.

(Architect) Project: improve safety on site. Potential negative impact on aesthetics. Firm: positive impact like sustainability. Marketing. Workers comp. Less litigation. Profession: Ditto, especially in improving relationships between architects and contractors. (He has really valued working daily with contractors.)

(Owner) Learning to ask the question: "How can we do this better?"

(Concrete contractor) Efficiencies (construction productivity), cost, safety. On the construction site, the safety will be just the same. Design drawings: not different than other project; difference will be in fabrication drawings.

(Drywall subcontractor) Safety will be much better. Lower cost. Higher quality. Changed culture/mindset.

(Owner) Cutting edge; project prestige; people want to work on it.

It would be very powerful to make a statement about DfCS at the beginning of a project. People like being on the cutting edge. DfCS could be prestigious.

(Electrical contractor) Top three hazards: Overtime leading to fatigue, overlapping trades, poor clean up. Also change in ladder safety is 'Huge. 4' ladder maximum on project'.

(Steel sub and concrete sub) Steel sub fabricated and detailed for safety, such as clips added during fabrication.

Project

How is this project different than typical DBB projects?

(Design engineer) IPD, which creates collaboration (although the dynamics are different on other Sutter projects that use IPD. Questioning the design. More aware of why the design is a certain way.

(Concrete contractor) Yes, different. I have no experience with DBB.

(Architect) On this project, there will be 100% agreement on how to build it at the end of design.

(Architect) It really is different. Final design will be better. Example: viscous wall dampers in lieu of base isolation. Faster to build, less expensive to build. Innovative. Perhaps safer.

(Architect) Architects have trade partners to collaborate with early in design. Use of BIM has enabled collaboration, allows quick reaction. Revit architectural, Revit structural, TEKLA, Inventor, CADDUCT, NAVISWORKS

(Drywall subcontractor) No competition internal between trades ("All for one, and one for all")

(MEP contractor) Everything is reimbursable throughout the entire project. Low experience factors will help owner's bottom line. On other projects, only lip service is given to mod factors.

(CM/GC) We have formal pricing and scheduling exercises on this project. We do not have formal safety exercises but safety issues are identified.

(Steel sub and concrete sub) Total different. Owner reportedly said "Rather than pay for litigation later, we will pay for proper design and planning up front."

How have these differences affected the application of DfCS?

(Design engineer) Not in a cognizant way.

(Concrete contractor) Yes, absolutely. Design controlled by A/E, not project team in DBB process.

(Architect) Yes, implicit from constructability reviews.

(Drywall subcontractor) Safety comes to the table as a prerequisite, not as a "reason why" to do it my way and not your way.

(MEP contractor) Yes, design is considering safety but best is yet to come as cluster meetings make progress in design. Example: steel—we are talking about guard cable, opening block outs, etc.

(CM/GC) On hardbid projects, options for influencing design are more limited.If you could start the project over, what DfCS-related thing would you differently?

(Design engineer) Less reactive to contractor requests; more proactive design.

(Architect) Process is working well.

(Architect) Current process is good; has allowed DfCS.

(Architect) Nothing. Right info has come at right time.

(CM/GC) Put DfCS in more explicitly. (Owner) Do the same way. Project is going very well. Meeting milestones.

(Concrete contractor) No. Maybe bring trade contractors in earlier.

(Drywall subcontractor) Make trade info more available to A/E team.

(Owner) Add safety professional on the project team.

(Owner) Idea of having a safety specialist responsible for DfCS is intriguing. Reporting out/accountability metrics help keep things on people's minds.

(MEP contractor) Put all liability on AE. Put in scopes of work, including GC scope too. Some decisions were made without trades' input, such as ceiling height and interstitial heights.

(Steel sub and concrete sub) Nothing.

Could the project DfCS processes work on all projects?

(Design engineer) No because lack of construction input.

(CM/GC) Hard to implement on projects without IPD.

(Owner) Not all firms if they don't like the IFOA.

(Concrete contractor) No, depends on team members. Need: right mindset, and collaboration.

(Architect) DfCS needs IPD, and could be applied to all projects.

(Drywall subcontractor) Yes, all projects. Need unique people, not just the firm.

(Owner) Any project size. Need people with the right mindset.

(Owner) Yes, as long as your partners have open minds.

To what extent does your permanent employer apply DfCS on other projects?

(Design engineer) None.

(Concrete contractor) Yes, on design-build projects.

(Architect) Not at all; not aware of it.

(Architect) (gave example of not wanting parapet wall for aesthetics reasons but willing to design a transparent parapet wall.) Built in anchorages on roof are being designed. Height of window is a big design decision so I would try to find out whether temporary barrier could be OK.

(Drywall subcontractor) Always.

(CM/GC) Firm's build-operate-transfer projects have incentives for designing for safe operations.

Other comments/info

(Architect) Ability to provide DfCS information depends on construction experience (very helpful to have the experience).

(Architect) "The design" is not just how it looks.

(Architect) If asked by owner, "We want DfCS, not IPD, what would you do?" – Not take on the project or hire construction knowledge.

(Architect) What industry is he in? "Customer service." Also, "design and construction industry." IPD have made walls between design and construction softer. "We are all part of same firm."

(Owner) Sutter Health is the "bank". CPMC is the owner.

(Owner) Metrics of IFOA: cost and schedule (no safety). Other tools tracking progress: pulse report.

(Owner) Sutter Health is open to adding safety to A/E selection.

(Owner) Sutter recognizes safety, but not aware of specific impact. Affects insurance, publicity, labor relations.

(Owner) Owner funds and helps troubled hospitals. Associated owner entity owns 27 hospitals. First owner mandated a lean approach on all future capital projects. Referenced IFOA, which delineates how major entities should behave.

(CM/GC) CM/GC does not have an OSH person in the office.

(CM/GC) Designers are part of the 25% pain/gain pool.

(CM/GC) Lean/IPD training has been critical on this project. The normal project system hammers people into bad habits.

(Drywall subcontractor) The subcontractor staff working on the project now may not be the same staff in the field. Field staff not here now. Need to ensure cross-over of both info and culture of collaboration.

(Drywall subcontractor) IPD is dependent on the IPD leader. It is different on other Sutter Health projects.(lead technical coordinator for architect) Architects do not just design how something looks. We coordinate a lot of things. We balance individual needs.

(MEP contractor) IPD is how it used to be in this industry. (One interviewee has 42 years of construction experience. Other interviewee is '96 AE graduate.)

(Steel sub and concrete sub) Concrete interviewee was originally on a complete different project team with a different scope and location and it was not an IPD project. Owner decided to start over and use IPD.

(Steel sub and concrete sub) This project has a lot of training to ensure all project participants are following processes and values the owner wants on this project. GC/CM has a Value guy.

Appendix 13: Microchip Manufacturer Case Study Survey Data

ID	Question 1(Heard of DfCS?)					Question 2(Attitude towards DfCS)			
	Never heard	Heard but Org. never considered implementing	Org. considered implementing but has never done	Org. has been involved with it on ltd. basis	Org. routinely ensures DfCS on projects	DfCS benefits do not seem compelling	DfCS benefits sound promising but barriers present	Will consider trying DfCS	Will implement DfCS
1					1				1
2					1				1
3					1				1
4				1					1
5					1				1
6	1								1
7					1				1
Total	1	0	0	1	5	0	0	0	7
Average									
Percent	0.14	0.00	0.00	0.14	0.71	0.00	0.00	0.00	1.00

ID	Question 3(Resources/ processes used to address CWSH)						
	CWS part of A/E scope per contract	Design checklists	Constructability reviews	In-house design guides	Computer program	Other	No specific processes/ resources
1	1	1		1		In-house	
2	1	1	1	1			
3		1	1	1			
4	1	1	1		1	Computer	
5	1	1	1	1		LCS walks	
6	1	1	1	1			
7	1	1	1	1			
Total	6	7	6	6	1		0
Average							
Percent	0.23	0.27	0.23	0.23	0.04		

ID	Question 4(Importance of DfCS to CWSH)					
	Not at all important	Less important	About the same importance	More important	Significantly more important	I don't know
1					1	
2			1			
3					1	
4			1			
5					1	
6			1			
7			1			
Total	0	0	4	0	3	0
Average						
Percent	0.00	0.00	0.57	0.00	0.43	0.00

ID	Question 5(Motivation to implement DfCS)							
	Competitive advantage	Improved CWSH	Improved facility OSH	Improved quality fo construction	Enhanced organization reputation	Reduced project costs	Shorter project schedules	Other
1	1	1	1	1	1	1		
2		1	1	1				More
3		1	1	1	1			
4		1	1	1	1			
5	1	1	1	1	1	1	1	Improved
6	1	1	1	1	1			
7		1	1	1		1		
Total	3	7	7	7	5	3	1	
Average								
Percent	0.09	0.21	0.21	0.21	0.15	0.09	0.03	

ID	Question 6(Barriers to DfCS)
	Barriers to implementing DfCS on organization's projects
1	Education training, paradigm that safety in design costs money, contracting strategies, right people arent always available at the right time,
2	Getting stakeholder organizations to recognize the benefits and fully buy in to the process. Once teams have used the process all the way
3	As a GC, this would vary according to the client, immediate time and cost impacts
4	The upfront time and cost involved in implementing and meetings for LCS. Also involving the correct people
5	very few
6	Cost Buy in from all parties
7	No answer
Total	
Average	
Percent	

ID	Question 7(Typical contract clauses hinder DfCS?)				Question 8(Support modifications to standard A/E contract documents?)				
	Company's contract wont change regarding A/Es DfCS ideas	Company's contracts could be changed regarding A/Es DfCS ideas	Company's contracts would be easily modified regarding DfCS ideas	Not Necessary to change company's contract	Yes	Yes, if no impact on other roles and responsibilities of A/E on a project	Yes, if no impact on Org. roles and responsibilities on a project	No, would not support modifications to the standard contract documents	Not familiar with standard contract documents
1				1	1				
2				1					1
3			1		1				
4			1			1			
5				1	1				
6				1					1
7				1					1
Total	0	0	2	5	3	1	0	0	3
Average									
Percent	0.00	0.00	0.29	0.71	0.43	0.14	0.00	0.00	0.43

ID	Question 9(A/E resistance as barrier to DfCS?)				Question 10(A/Es capable of performing DfCS)				
	A/Es will never agree and Org. cannot force	A/Es will resist, but Org. can insist the A/Es	Some A/Es will agree, some will disagree	Most of A/Es will gladly perform DfCS	Most A/Es could never learn enough	Most A/Es could learn enough	Most A/Es could perform DfCS using assistance	Most A/Es could easily learn	Most A/Es already capable
1				1					1
2				1			1		
3			1				1		
4			1				1		
5				1			1		
6				1			1		
7				1				1	
Total	0	0	2	5	0	0	5	1	1
Average									
Percent	0.00	0.00	0.29	0.71	0.00	0.00	0.71	0.14	0.14

ID	uestion 11(% more in design fee	Question 12(Increase in A/E fees a barrier?)				Question 13(Liability of Org. w.r.t DfCS)		
	Upto _% more in design fees to perform DfCS	DfCs will never happen due to increased fees by A/Es	Higher design fees could become acceptable	Increased design fees could be justified to higher management	No or modest increase in fees by A/Es	will increase liability exposure	will not affect liabililty exposure	decrease liability exposure
1	No answer			1				1
2	No answer				1	No answer		
3	No answer			1				1
4	4%		1					1
5	10%			1				1
6	No answer			1				1
7	No answer				1			1
Total		0	1	4	2	0	0	6
Average								
Percent		0.00	0.14	0.57	0.29	0.00	0.00	1.00

ID	Question 14(Reasons for non-implementation of DfCS)						
	Not applicable	Too costly	Added design duration	No perceived benefit	Not enough information/ knowledge about DfCS	Higher priority for other project objectives	Other
1	No answer						
2	No answer						
3							The client
4	1						
5							NA,
6	No answer						
7	No answer						
Total	1	0	0	0	0	0	0
Average							
Percent	1.00	0.00	0.00	0.00	0.00	0.00	0.00

ID	Question 15(Org.'s priority criteria w.r.t construction projects)							
	Aesthetics	Construction worker safety & health	Facility user safety & health	Maintenance worker safety & health	Project cost	Project schedule	Quality of final product	Other
1	7	1	3	2	5	6	4	
2	6	1	1	1	4	3	2	5(ability to
3	6	2	3	5	1	3	7	
4	7	1	3	2	5	6	4	
5	5	1	1	1	3	4	2	
6	7	1	5	6	4	3	2	
7		1	4	4	3	2	4	
Total								
Average	6.33	1.14	2.86	3.00	3.57	3.86	3.57	
Percent								

ID	Question 16 (Change in the following items as a result of DfCS)							
	Construction injuries				Design costs			
	Decrease	No change	Increase	I don't know	Decrease	No change	Increase	I don't know
1	1					1		
2	1					1		
3	1						1	
4							1	
5	1					1		
6	1						1	
7								
Total	5	0	0	0	0	3	3	0
Average								
Percent	1.00	0.00	0.00	0.00	0.00	0.50	0.50	0.00

ID	Question 16 (Change in the following items as a result of DfCS)							
	Construction costs				Total project costs to the owner			
	Decrease	No change	Increase	I don't know	Decrease	No change	Increase	I don't know
1		1				1		
2	1				1			
3			1				1	
4	1				1			
5	1				1			
6		1					1	
7								
Total	3	2	1	0	3	1	2	0
Average								
Percent	0.50	0.33	0.17	0.00	0.50	0.17	0.33	0.00

ID	Question 16 (Change in the following items as a result of DfCS)							
	Design durations				Construction durations			
	Decrease	No change	Increase	I don't know	Decrease	No change	Increase	I don't know
1				1				1
2			1		1			
3			1				1	
4			1		1			
5		1			1			
6			1			1		
7								
Total	0	1	4	1	3	1	1	1
Average								
Percent	0.00	0.17	0.67	0.17	0.50	0.17	0.17	0.17

ID	Question 16 (Change in the following items as a result of DfCS)							
	Total design and construction durations				Construction quality			
	Decrease	No change	Increase	I don't know	Decrease	No change	Increase	I don't know
1				1			1	
2	1				1			
3			1					
4		1					1	
5	1						1	
6			1				1	
7								
Total	2	1	2	1	1	0	4	0
Average								
Percent	0.33	0.17	0.33	0.17	0.20	0.00	0.80	0.00

ID	Question 16 (Change in the following items as a result of DfCS)							
	Number of lawsuits against owners				Number of lawsuits against A/Es			
	Decrease	No change	Increase	I don't know	Decrease	No change	Increase	I don't know
1	1				1			
2				1				1
3	1				1			
4	1				1			
5	1				1			
6				1				1
7								
Total	4	0	0	2	4	0	0	2
Average								
Percent	0.67	0.00	0.00	0.33	0.67	0.00	0.00	0.33

ID	Question 16 (Change in the following items as a result of DfCS)			
	Reputation of A/Es within society			
	Decrease	No change	Increase	I don't know
1			1	
2				1
3			1	
4			1	
5				1
6			1	
7				
Total	0	0	4	2
Average				
Percent	0.00	0.00	0.67	0.33

ID	Question 17
	Changes made or needed to Org. structure &/or project development process
1	None
2	No answer
3	It comes down to the client, what the client is willing to pay
4	Contract language and schedule considerations to allow time and owner buy in to program
5	safety as a core value
6	Just more time and effort during design
7	
Total	
Average	
Percent	

ID	Question 18	Question 19(Organization's category?)					
	What would enable or assist DfCS on Org. projects	Owner	Designer(A/E)	Design/ Builder	GC/CM	Trade contractor	Other
1	None	1					
2	No answer	1					
3	No answer				1		
4	Records of the realized benefits to sell the concept				1		
5	NA, already fully engaged	1					
6	Getting signed up early in the design	1			1	1	
7							
Total		4	0	0	3	1	0
Average							
Percent							

ID	Question 20(Activities performed by Org.'s employees)						Question 21(% of Org.'s market sector)	
	Site civil and/or geotech engineer	Structural engineering	Mechanical systems engineering	Construction	Construction Management	Other	Public sector(%)	Private sector(%)
1	No answer							100
2	1	1	1		1	process,		100
3				1	1		40	60
4				1	1		50	50
5					1	Design		100
6				1	1			
7					1			100
Total	1	1	1	3	6			
Average							45.00	85.00
Percent								

ID	stion 22(No. of employ	Question 23(% of Org.'s market segment)				uestion 24(% of IPD utilizatio	n 25(% constructed by Org
	Organization has approximately __ employees	Commercial(%)	Industrial(%)	Infrastructure / heavy civil(%)	Residential(%)	% of organization's projects uses some type of integrated project delivery approach, e.g. deign-build/ CM at risk etc.	% of organization's projects constructed by organization's own employees
1	300		100			100	No answer
2	30		100			100	0
3	160	80	20			50	20
4	10000	25	25	50		75	25
5	3500	10	80	10		20	0
6							
7			100			100	0
Total							
Average	2798.00	38.33	70.83	30.00	#DIV/0!	74.17	9.00
Percent							

ID	Question 26(Organization's facility locations)											
	Northeast U.S.	Mountain states	Midwest U.S.	Mid-Atlantic U.S.	Southwest U.S.	Europe	Southeast U.S.	West Coast	Caribbean	South America	Asia	Middle East & Africa
1		1				1		1			1	
2	1					1	1				1	
3	1	1	1	1	1	1	1	1		1		
4	1			1	1	1	1	1				
5	1	1		1	1	1		1	1	1	1	
6								1				
7												
Total	4	3	1	3	3	5	3	5	1	2	3	0
Average												
Percent												

Appendix 14: Microchip Manufacturer Case Study Interview Compilation

Note: LCS = Life Cycle Safety, which is the term used to refer to the firm's safety management program.

Drivers

Who is the primary driver of LCS on this project?

(Owner – I&C Lead): Owner

(Owner – Process Lead): Owner – Construction Engineering Group

(Owner – CSA Lead): Owner

(Owner – Design Manager): Owner – Project Engineering

(CM – EHS): Owner

(CM – Electrical Superintendent): Owner – Construction Services Division

(CM – Commissioning Manager): Owner and CM (50/50)

(Owner – Corporate EHS): It depends on the level of the project. Owner drives it through the contract; the A/E makes it happen.

What do you think is their primary motivation for pursuing LCS?

(Owner – I&C Lead): Influencing a safer facility.

(Owner – Process Lead): Injury-free environment. Use of a safe facility for operations.

(Owner – CSA Lead): Safety is a core value for Owner. Safety is valued by all of Owner: enlightened view and good for business. Injury and incident free environment.

(Owner – Design Manager): Safer construction and operations. Design out the hazards.

(CM – EHS): Owner sees the long-term benefits of better safety and health.

(CM – Electrical Superintendent): To have the best facility: safest construction, maintainability, injury-free environment.

(CM – Commissioning Manager): Safety for all of the parties.

(Owner – Corporate EHS): For Owner: safety and to be a safety leader. For A/Es: contract compliance.

What is your primary motivation for participating in LCS?

(Owner – Process Lead): Same as Owner: Injury-free environment. Use of a safe facility for operations.

(Owner – CSA Lead): Safety is a core value. Focus on designing for the person; make it an enriched environment.

(Owner – Design Manager): I am fully behind the Owner goals. Personal satisfaction to improve. Makes my job easier.

(CM – EHS): Safety (personal). For CM: a streamlined process, making the client happy, and safe workers.

(CM – Electrical Superintendent): Safe construction, maintainability, and injury-free environment, and to improve the design.

(CM – Commissioning Manager): Benefit to workers (safety).

(Owner – Corporate EHS): Safety. Maintenance safety also.

Would LCS have been implemented if the primary driver was not interested in it?

(Owner – I&C Lead): A/E's would not implement this; must be owner driven. A/E has no incentive.

(Owner – Process Lead): No.

(Owner – CSA Lead): No. It will not happen if it is not valued by the owner (client).

(Owner – Design Manager): It would not automatically develop. Needs a champion.

(CM – EHS): CM constructability reviews. Cost is a factor; if CM owned the design, then maybe they would drive it (contractual issue).

(CM – Electrical Superintendent): Others would implement. For example, "bulletproofing" walks by the construction manager.

(CM – Commissioning Manager): No.

(Owner – Corporate EHS): Yes.

Processes

What did the owner do initially to initiate and enable LCS?

(Owner – I&C Lead): LCS process starts in Programming phase. A/E RFP and contract includes participation in LCS.

(Owner – Process Lead): Training on LCS. Partner with A/E firm to drive it during project. LCS walk around project site at about 60% design.

(Owner – CSA Lead): Developed a corporate champion for LCS. Created training material. Ergonomics first thing addressed. (Note: This response is primarily in regards to the development of the LCS process initially as opposed to its implementation on the project being considered.)

(Owner – Design Manager): Package training session at the start: purpose, how to do it. LCS checklist during Programming and Scope Development. LCS walks and page-turn reviews.

(CM – EHS): Don't know how LCS was initially started. On this project, LCS walks.

(CM – Electrical Superintendent): A/E schedules LCS walks. Looking for improvements.

(CM – Commissioning Manager): Problems looked at earlier in the design. Improvements in the working environment.

(Owner – Corporate EHS): It started with the original D1D fab project. Not sure exactly how it was implemented.

How do LCS opportunities get identified?

(Owner – Process Lead): LCS walk around project site. LCS "page turn" review session. LCS checklist (list of things to think about).

(Owner – CSA Lead): LCS walk through the facility at approximately 60% design with the A/E and contractor. Checklist and form used. Inputs gathered and vetted.

(Owner – Design Manager): LCS walks, checklists, design reviews.

(CM – EHS): Page-turn reviews on the initial design scope (access, height, etc.). LCS walks around the site.

(CM – Electrical Superintendent): Checklist which consists of a general list of things to look for. Need to "imagine" what will be going on during construction.

(CM – Commissioning Manager): 60% design review, and LCS walks. All parties jointly do walks and come up with a list of items that need to be addressed.

(Owner – Corporate EHS): An LCS checklist, LCS project team meetings periodically throughout the project, and LCS walks around the site.

How are LCS design decisions made? Who makes them and how are meetings, emails or phone conversations used?

(Owner – Process Lead): Owner discipline leads primarily, and collaborative discussion amongst project team. Lots of control by Owner on the process, and also in general regarding the projects.

(Owner – CSA Lead): Decisions are made by the work group chaired by Owner project engineer for discipline along with A/E, contractor, and subs. Review of work sequence and hazards.

(Owner – Design Manager): There is a change control process implemented. Some decisions are made at the project level, some at a higher level.

(CM – EHS): Managers of work group decide during LCS project team meeting. Funding is an issue; must justify costs.

(CM – Electrical Superintendent): Send out notes for review in an e-mail; notes are reviewed at the next LCS review meeting. Issues are resolved at the meeting with Owner having the final decision.

(CM – Commissioning Manager): CM/GC gets the info and reviews. LCS walks, and work group meeting.

(Owner – Corporate EHS): Decisions are made collectively without any one specific person taking charge every time. It often depends on the personalities of the people in the room during meetings.

What is the form and content of LCS information that is communicated?

(Owner – CSA Lead): List of review items (checklist) and spreadsheet for recording responses and actions.

(Owner – Design Manager): Checklist. Capture comments in a log. Identify residual risk.

(CM – EHS): Checklist.

(CM – Electrical Superintendent): Via e-mail, a checklist.

(CM – Commissioning Manager): LCS walks and checklist. Also lessons-learned, idea communication. Sit down in a meeting and group communication about the issues. Best known methods by Owner discussed.

(Owner – Corporate EHS): Numerous documents to assess risk, and the checklist.

What phases of construction have had stronger LCS consideration? Why?

(Owner – I&C Lead): LCS covers the entire lifecycle.

(Owner – Process Lead): Earlier is better. Greater impact with: Process, Mechanical, and Civil/Structural/Architectural.

(Owner – CSA Lead): 60% design is default (enough info available at this time, but not too late). Difficult to design out hazards related to steel-erection.

(Owner – Design Manager): 60% reviews. Discipline depends on the job; good for process and mechanical.

(CM – EHS): Earlier the better. Can do from field also (RFI). LCS has more impact on dry and wet mechanical.

(CM – Electrical Superintendent): About 30-60% design is effective. Most impact on architectural and process and instrumentation disciplines. Not so much on electrical.

(CM – Commissioning Manager): 60% design, ends when package is issued for construction.

(Owner – Corporate EHS): During base build as opposed to tool install. During design is good, however need to have contractors identified to get construction input. Biggest benefit occurs in process mechanical (routing, size, type of pipes, etc.).

What LCS-related information was initially possessed by each of the following entities? What about now?

Owner

(Owner – Process Lead): Lots.

(Owner – CSA Lead): To some degree. Varies per work group.

(Owner – Design Manager): Depends on the individuals involved. Owner provides lots of input.

(CM – EHS): Yes

(CM – Electrical Superintendent): Depends on the owner's representative; if it is the tech who runs the system, then very good.

(CM – Commissioning Manager): Depends on who is involved.

(Owner – Corporate EHS): Yes, the Owner engineer, not the Owner PM.

A/E

(Owner – Process Lead): Depends on skills and knowledge of A/E.

(Owner – CSA Lead): Contributes some.

(Owner – Design Manager): Less; more involved as facilitators.

(CM – EHS): Design info and some knowledge of how to design for safety.

(CM – Electrical Superintendent): Rely on field staff to identify hazards.

(CM – Commissioning Manager): Not that much. Mostly design, not site hazards.

(Owner – Corporate EHS): Not as much; play more of a role as the facilitator. More design input as opposed to input on the hazards.

GC/CM

(Owner – Process Lead): Yes, lots.

(Owner – CSA Lead): Most knowledgeable, although varies per work group.

(Owner – Design Manager): Good input.

(CM – EHS): Give most input and list of options

(CM – Electrical Superintendent): Yes.

(CM – Commissioning Manager): Good input.

(Owner – Corporate EHS): Yes, but not the primary input.

Trade partners

(Owner – Process Lead): Some, and getting better.

(Owner – CSA Lead): Yes, some. Field exposure helps. Varies per work group.

(Owner – Design Manager): Good input.

(CM – EHS): Yes.

(CM – Electrical Superintendent): Yes.

(CM – Commissioning Manager): Good input.

(Owner – Corporate EHS): Yes, significant. They know what is acceptable and what is not acceptable.

Barriers/Enablers/Impacts

How is safety addressed relative to other priorities such as cost, schedule, and quality?

(Owner – I&C Lead): Cost of LCS is in the "noise of a contract". It is insignificant. During option evaluation, cost is never an issue.

(Owner – Process Lead): Safety is No. 1 by far (then schedule and cost). Can always get schedule relief if it is a safety issue. Production is important, just like safety.

(Owner – CSA Lead): Historically it was schedule that took priority (get microchips out as fast as possible). Now it is cost and schedule that commonly takes priority.

(Owner – Design Manager): All have a part. What is true safety impact is sometimes a question. More convenience may be safety issue but low cost.

(CM – EHS): Safety is No. 1 priority.

(CM – Electrical Superintendent): Cost not an issue.

(CM – Commissioning Manager): Safety is taken care of. Cost is a boundary. All priorities are equal; not always just one way.

(Owner – Corporate EHS): Safety is preached as #1, however all priorities are considered together. As opposed to 15 years ago, now we are smarter about assessing risk related to an alternative to make decisions. Previously, if safety was tied to a change, it was done no matter what; now a risk evaluation is done to guide whether to implement or not.

What do you feel are the most important barriers to implementing LCS on your organization's projects?

(Owner – Process Lead): Owner system owner buy-in. Sometimes they don't understand why they should be part of it. On the project site, we have the same problems today as on the sites 15 years ago.

(Owner – CSA Lead): Cultural issues: status quo and resistant to change once used to a particular system. Risk of liability. 90% of incident reports result from straying from the pre-task plan.

(Owner – Design Manager): Lack of a site champion. Need people to understand it and its value. Need engagement with Owner system techs.

(CM – EHS): Client's budget.

(CM – Electrical Superintendent): Availability of time and having the right people involved. Ability to visualize the design.

(CM – Commissioning Manager): Ability to look at things upfront before they are built (visualization). Availability of funds to implement the suggested designs.

(Owner – Corporate EHS): Lack of "ownership" of the LCS process (i.e., a person/group/firm that is responsible for implementing LCS on the project). There is no LCS component included in site reviews and incident audits. There is no accountability for implementing LCS measures. It is not a legal requirement; making it a legal requirement will remove barriers.

What changes to your organization's structure and/or project development process were made, or would be needed, in order to implement LCS on projects?

(Owner – Process Lead): Don't know yet.

(Owner – CSA Lead): Discipline leads are identified for each organization. Structured LCS reviews and walks for all projects. Answer questions brought up regarding safety and health before package released for construction.

(Owner – Design Manager): None. Just need training.

(CM – EHS): Partner with Owner. No other changes needed.

(CM – Electrical Superintendent): Make it a contract requirement as part of the job. Preconstruction involvement of all of the parties.

(CM – Commissioning Manager): At 60% review, LCS is one of the main points of focus. LCS cannot be put on the back burner.

(Owner – Corporate EHS): More time added in the project schedule to conduct the LCS meetings.

What would enable or assist your organization in implementing LCS on your organization's projects?

(Owner – Process Lead): Safety mentality (positive and injury free). Owner has safety and health as a core value. Also, Owner's re-showing to trades during the project that "we are committed to this".

(Owner – CSA Lead): A champion of the process.

(Owner – Design Manager): Owner's focus on safety.

(CM – EHS): Client involvement. Trade involvement. Safety culture: injury-free environment.

(CM – Electrical Superintendent): Data showing the benefits of LCS in order to sell it to the owners. Cost decrease due to LCS.

(CM – Commissioning Manager): Owner driving it.

(Owner – Corporate EHS): Research findings that show the impact and costs/benefits of LCS in order to show its value. Owner is a very data driven company. Hard data is commonly needed to demonstrate the need for a change.

What have been, or do you foresee will be, the impacts of implementing LCS?

(Owner – I&C Lead): More of a sense of "we" amongst project team members. Better sense of shared responsibility.

(Owner – Process Lead): Much more thorough designs (design were not complete before). Long-term costs are less (maintainability, demolition). Helps safety. Trade contractors know that they will go home every day.

(Owner – CSA Lead): Fewer injuries. Better constructability. Better designs (quality-wise). New culture more focused on S&H. Working together with productivity, cost, and constructability. Closer to having a mindset of designing out the hazards rather than just implementing PPE or other.

(Owner – Design Manager): Better designs; fewer changes in the field; fewer errors and omissions. Hard to quantify the impact on safety.

(CM – EHS): Safer worksite, long-term quality of the facility, and long-term cost savings.

(CM – Electrical Superintendent): Safer project, injury-free installation, maintenance friendly final product, and happy customer (owner).

(CM – Commissioning Manager): Helps out with less retrofit. Safety the first time. More efficient construction. Safety and efficiency.

(Owner – Corporate EHS): Better design. Fewer injuries; less risk. Additional cost, although long-term positive return on investment.

Project

How is this project different than typical DBB projects?

(Owner – Process Lead): Could do on DBB project, but need GC dominant and driver of the process. Much better with IPD process.

(Owner – CSA Lead): Pre-design, pre-scoping meetings take place. LCS walks by project team during design. LCS discussions (pre-bid conference). Collaboration, communication, and better understanding of project.

(Owner – Design Manager): This is a CM/GC project. Without the CM/GC, would need to go directly to the GC and subs.

(CM – EHS): It will work on DBB projects if it is addressed in the contract.

(CM – Electrical Superintendent): Communication. Involvement of the owner, A/E, and contractor in every design phase. LCS walks in every scope, every package.

(CM – Commissioning Manager): Hard sell on DBB projects. Need right business practice and mindset.

How have these differences affected the application of LCS?

(Owner – CSA Lead): Improved and made LCS easier. Change to the culture (improved LCS).

(Owner – Design Manager): IPD not requisite. Slightly more administration under DBB.

(CM – Electrical Superintendent): Better finished product, and improved life cycle safety. LCS is a good tool. Additional cost initially, and improved safety.

(CM – Commissioning Manager): Depends on how the Project Managers feel about it (i.e., if they push it).

If you could start the project over, what LCS-related thing would you differently?

(Owner – Process Lead): Get Owner system owner buy-in or joint-driving (not just driven by discipline leads).

(Owner – CSA Lead): Improve lessons-learned database. Implement a plan, do, check, act process. Improve the checklist.

(Owner – Design Manager): No changes needed.

(CM – EHS): Generate more buy-in from the internal Owner system owners.

(CM – Electrical Superintendent): More time in design is needed. Two LCS walks initially in design, and one later for a check.

(CM – Commissioning Manager): More attention to the design (currently not enough time to look at everything).

(Owner – Corporate EHS): Making it a documented policy or process that is "owned" by a group within Owner.

Could the project LCS processes work on all projects?

(Owner – CSA Lead): Yes, it is feasible.

(Owner – Design Manager): Yes.

(CM – EHS): Yes.

(CM – Electrical Superintendent): Yes, if the process is understood up-front.

(CM – Commissioning Manager): Yes. Need a champion.

(Owner – Corporate EHS): Yes, all projects. Also, all owner firms.

To what extent does your permanent employer apply LCS on other projects?

(Owner – Process Lead): It is applied system-wide (all capital projects).

(Owner – CSA Lead): It is changing. All projects outside the U.S. have LCS people pushing implementation of LCS and teaching its benefits. People are accepting and are willing to change.

(Owner – Design Manager): Heavily implemented on other Owner projects including on nearby Aloha campus. Starting at other campuses worldwide; need a champion at each site.

(CM – EHS): Yes, constructability reviews and mitigation walks.

(CM – Electrical Superintendent): 75% of preconstruction, LCS concept applied officially.

(CM – Commissioning Manager): CM has a little bit.

(Owner – Corporate EHS): To a limited extent. Still needs to verify if it is in the contracts at other Owner sites.

Other

(Owner – I&C Lead): Compared to other safety and health programs implemented on construction projects, LCS is the primary form of protection.

(Owner – I&C Lead): Q: Since LCS has been implemented, is there now less of a need to implement other safety programs/elements/tools during construction? A: Yes.

(Owner – Corporate EHS): Current obstacles to the LCS process in Owner is that there is no identified LCS group, person, or division to be the champion. There needs to be ownership of the process to make sure it happens, and currently nobody or no group officially "owns" it. So its implementation can be spotty. The challenge is making is a corporate-wide goal. It has been implemented for basebuild projects, but not as significantly for tool install projects. Need to make it a formal requirement; who "owns" it needs to be decided for every project. The Corporate Construction EHS Office should be the owner of it for Owner. Ways to get A/Es to be more responsive include: including LCS in the periodic A/E evaluations (Report Cards); including an LCS line item in incident review forms to track the connection of the incident to the design.

Appendix 15: Microchip Manufacturer Case Study Life Cycle Safety Documents

Description of the Owner's Life Cycle Safety (LCS) Process

(Source: "D1D Life Cycle Safety Process: Purpose, Development, Application and Implications for Future Projects." Report on the D1D Life Cycle Safety Process, Nov. 25, 2002.)

Purpose

The purpose of engaging in the LCS process was three fold. First and foremost was to have a process that systematically considers the design of the building for possible safety impacts through all phases of the lifecycle of the facility. The lifecycle phases include:

Constructability
Operability
Maintainability
Retrofit
Decommissioning
Demolition

It was intended to consider each of these lifecycle phases during each phase of design of the facility. The design phases include:

1. Programming,
2. Detailed Design,
3. Field Design,
4. Tool Install
5. Start-up
6. Conversion
7. Demolition

Second, LCS provides a formal process for getting feedback from stakeholders pertaining to each phase of the lifecycle of the building. Individuals involved at each phase of the building are in the best position to know how potential designs will impact their safety. For example, construction trade contractors who have experience building fabs have insight on how the design helps or hinders safe construction. Similarly, operators that will occupy the fab can provide input into how the design impacts their ability to operate the fab safely.

Finally, the overall impact of this process approach is advancement of the concept of an Injury Free culture through engagement of the project's community in evaluation and planning. This not only positively impacts safety, but also cost, quality, and productivity as well. This visible restatement of the value of safety and the unwillingness to place people at risk remains a cornerstone of the Owner's Injury Free culture.

LCS in Programming

The LCS process includes targeted trade contractors in the Programming phase in several ways. Ad-hoc meetings with trade contractors are held to focus on specific options for evaluating implications for constructability, value engineering, and safety. To make further use of trade contractor expertise, a procurement strategy is used to bring key contractors on-board to participate in workgroup and design option evaluations. These contractors provide pre-construction and pre-design services, and

offer an expertise traditionally unavailable in this project phase. A subsequent procurement phase balances providing trade contractor expertise to support schedule and LCS goals with contracting strategies focused on the project's cost goals.

A Safety in Design checklist, which evolved from previous projects, is used and provides a foundation for the LCS workgroup. The checklist contains design suggestions on how to improve safety through the design that have been collected from literature and previous projects. The checklist is provided to the discipline workgroups to be addressed during Programming, and also during Schematic/Detailed Design and Construction phases.

The LCS resources include a process flowchart designed to integrate the evaluation of design options for LCS into the Owner's Change Control Process. A flowchart that describes the Change Control Process is provided in Figure 1.

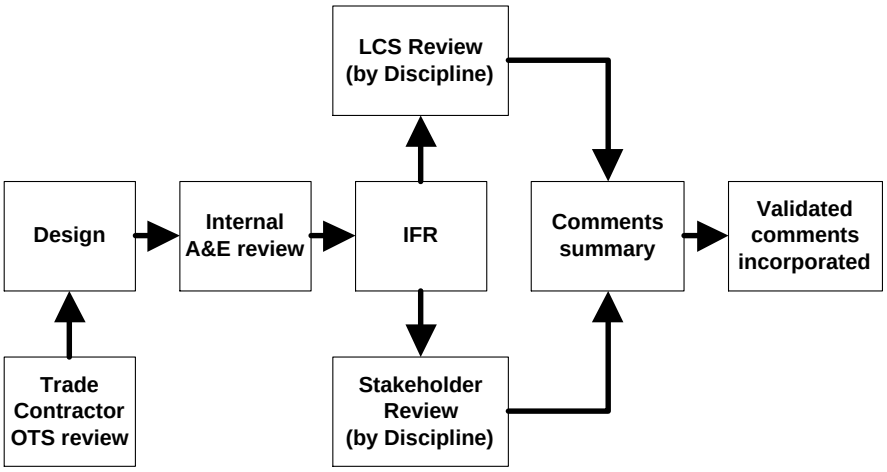

Figure 1: Design Change Review Process

Several tools are used as part of a total evaluation plan to assist workgroups in systematically addressing each project goal and provide a graphical representation of their findings. Each tool was developed to address a specific part of the evaluation. The Change Evaluation Checklist and supporting Project Goal Evaluation Worksheet provide a comprehensive view of each workgroup's assessment against each of the project goals. The Option Evaluation Sheet (Figure 2) and Option Summary provide each workgroup with a way to quantify the pros and cons of each option against the project goals. These tools also allow multiple options to be compared against each other.

Option Evaluation Sheet — Intel D1D Programming

Option Title

Option Description

Description of Issue:

	Evaluation Criteria *FSCS GOALS*	wt.	Score: worse 5- *0 better 5+	total	Comments
C1	Dollars / Sq Ft	1		0	
C2	Tool Install Cost	1		0	
E1	Energy Conservation	1		0	
E2	Reduce Emissions	1		0	
S1	Support 2 Technology and 5 HVM Generations	1		0	
S2	Maintain Existing Reliability and Maintainability	1		0	
S3	Improved Life Cycle Safety	1		0	
S4	Maximize Reuseability and Fungibility	1		0	
D1	Overall Construction Duration	1		0	
D2	Consructability	1		0	
D3	Tool Install Duration	1		0	
		1		0	
				0	Total Score

Comments:

Figure 2: Option Evaluation Sheet

The Risk Comparison Form (Figure 3) and a Risk Mitigation Form (Figure 4) were developed to assist in specifically evaluating hazards for options under consideration and proposing mitigation strategies for phases of the building lifecycle. These phases are Construction, Tool Install/Retrofit, and Facilities and Manufacturing Operations & Maintenance. A report on the evaluations is included in the weekly Project Team Review.

D1D Life Cycle Safety Evaluation

RISK COMPARISON

Description: Subfab height / Basement Decision

Evaluation By: LCS WG (1/19/01)

Instructions: *1. Compare each option against POR. Options with risks equal to the POR option are assigned 0.*
2. Assign a relative value from -5 (high risk relative to POR) to +5 (low risk relative to POR) to each risk.
3. Using the attached checklist as a guide identify Risk associated with each of the four specific categories.
4. Identify the Work Group or Area Group performing the evaluation.
5. Include the evaluation as backup to the presentation for the particular option.

Category	Risks	Relative Evaluation of Options					
		POR	16'9"	2 SF			
Construction	**subtotal**	**0**	**-1**	**7**	**0**	**0**	**0**
	Trench construction and deep AWN pit create excavation hazards relative to cave-in. After backfill of trench/AWN, fall exposures remain during basebuild.	0	0	2			
	Increasing height of subfab requires taller ladders & ladders on catwalks to access utilities during basebuild. Increased fall exposure and use of subfab space for wider bases.	0	-1	0			
	Access to tie-off points for fall protection difficult due to utility congestion and rack design.(e.g. Electrical distribution, duct sizing)	0	-1	2			
	Elevated material handling of large conduit in central trench because in slab locations under subfabs	0	0	1			
	Congestion of utilities in overhead (from electrical distribution & duct sizing) creates limited routing for other utilities, awkward postures, difficult access.	0	1	2			
RetroFit/Tool Install	**subtotal**	**0**	**3**	**8**	**0**	**0**	**0**
	Cutshops & pre-fab areas remote from fab/subfab. Increased material handling.	0	0	1			
	Congestion in subfab requires climbing out on steel over the utilities increasing exposure to fall.	0	1	2			
	Increasing height of subfab requires taller ladders & ladders on catwalks to access utilities during tool install & retro-fit. Increased fall exposure and use of subfab space for wider bases.	0	-2	0			
	Access to tie-off points for fall protection difficult due to utility congestion and rack design.(e.g. Electrical distribution, duct sizing)	0	1	2			
	Congestion of utilities in overhead (from electrical distribution & duct sizing) creates limited routing for other utilities, awkward postures, difficult access.	0	1	2			
	Catwalk height and utility space options create head-knockers.	0	2	1			
Mfg. O&M	**subtotal**	**0**	**0**	**5**	**0**	**0**	**0**
	Subfab congestion. Restricted access to equipment for PMs.	0	0	1			
	Leaks & drips into tool's electrical equipment.	0	0	3			
	Housekeeping issues due to restricted space for spare parts & PM supplies.	0	0	1			
Facilities O&M	**subtotal**	**0**	**0**	**14**	**0**	**0**	**0**
	Increasing height of subfab requires taller ladders & ladders on catwalks to access utilities during basebuild. Increased fall exposure and use of subfab space for wider bases.	0	-1	0			
	Access to tie-off points for fall protection difficult due to utility congestion and rack design.(e.g. Electrical distribution, duct sizing)	0	-1	2			
	Subfab congestion. Restricted access to equipment for PMs.	0	0	2			
	Leaks & drips into facility electrical equipment.	0	0	3			
	Access to isonlation valves and POCs.	0	1	2			
	Working above energized equipment at stacked transformers.	0	0	2			
	Overflows due to use of bucket pumps.	0	0	1			
	Sprinkler head obstruction by utility congestion.	0	1	2			

Figure 3: Risk Comparison Form

D1D Life Cycle Safety Evaluation

MITIGATION PLAN

Description:

Evaluation By:

Instructions: *1. Complete this evaluation for each change or option being evaluated.*
2. Using the attached checklist as a guide, identify risk associated with each of the four specific categories. Add lines as required.
3. For each risk, identify what is required to mitigate the risk. In doing so you should evaluate if the risk can be minimized through design.
4. Identify the Work Group or Area Group performing the evaluation.
5. Include the evaluation as backup to the presentation for the particular option.

Category	Risks	Mitigation
Construction		
RetroFit/Tool Install		
Operation		
Maintenance		

Figure 4: Risk Mitigation Form

LCS in Detailed Design

During schematic and detailed design, the Construction Manager (CM) and Trade Contractors support the design team during design development prior to the reviews. Periodic meetings and consultation are coordinated by the specific Work Group. Internal reviews by the AE are expanded to include addressing issues identified in the Safety and Design Checklist and adjudication of issues raised in previous LCS reviews for that particular design package. A flowchart of the review process is shown in Figure 5.

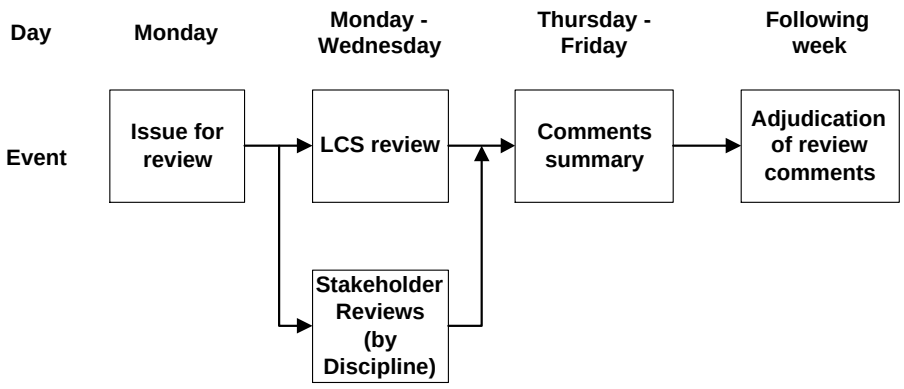

Figure 5: Design Review Schedule

Project reviews are held at three phases: Schematic Design, Design Development, and Construction Documents. After documents are issued for review (IFR), parallel reviews are held. Traditional owner reviews are discipline-based and include stakeholders. A separate LCS review that includes Owner construction site technicians, Trade Contractors, and EHS staff are held to focus on constructability, maintainability, and multi-discipline coordination with an area focus. Comments from each review are gathered and responses to each issue accompany the package through additional reviews and procurement. Field coordination and design issues that remain are identified and communicated to the CM and Trade Contractors for facilitating the Activity Hazard Analysis (AHA) that precedes that scope of work.

The inclusion of the Trade Contractors early in the project not only provides the work groups with an opportunity to gain from Trade Contractor experience in constructability, cost, and LCS evaluations, but also the opportunity for Trade Contractors to become engaged as project participants sharing in meeting all the project goals. Roles and responsibilities of the project team for facilitating Trade Contractor involvement in the design process are provided below. This opportunity not only bodes well for the project, but also for building the safety culture that will create and maintain an injury free environment on the Owner's campus.

LCS in Basebuild Construction

The total list of LCS adjudicated comments is provided to the CM to be included in the Procurement Package. The intention is to provide the Trade Contractors with an understanding of issues that have been addressed through the design and highlight issues that need resolution through construction sequencing or means and methods. The CM reviews and approves Trade Contractors' AHAs during the Mobilization Process. The AHA's are focused on the scope of work associated with the award. Owner and the CM's Work Group leads and EHS staff participate in these reviews.

The CM pilots cross-discipline/trade work sessions to allow all of the organizations involved with a specific package to plan for hazards that might be generated through the construction sequence. These Phase Safety Roadmap sessions use the adjudicated comments while exploring sequencing, means and methods, and organizational roles and responsibilities. This process may be implemented to varying degrees, which generates mixed results.

LCS during PSSS & Tool Install (PSIT)

The project PSSS packages use the LCS review process developed under the Basebuild scope. Reviews of the Tool Install packages (LSP's) were built on the extensive work done previously that focused on how the equipment supported safe operation for factory technicians. This tool focus is comprehended in the Owner's "Cradle to Grave" concept and actually starts prior to equipment being docked at the prospective fab no matter where the location.

World Wide Fab Technology Design Environmental Health & Safety (WWFTDEHS) helps write the templates for process equipment purchase contracts. Within this template, generic requirements pertaining to environmental compliance, chemical use, preventative maintenance, operation, and installation are included. These requirements also include compliance to SEMI S2-0200, SEMI S8, NFPA 79, NEC, Uniform/International Building, Fire, Mechanical and Plumbing codes and Owner EH&S requirements. These codes/Owner requirements involve the safe installation, operation, and maintenance of the equipment.

The PSIT organization performs detailed design reviews on the equipment looking at technical and EHS issues involved with the tool install. If trades have been contracted to attend the meeting they are typically looking for technical issues on the design plus they may come up with difficulties in installing specific portions of the equipment such as exhaust duct and electrical gutters. During design reviews, EHS utilizes the Process Equipment Installation Design Guideline to help identify EHS issues before the tool is installed. The Design Guideline is a mature document that is code and Owner requirement-based and is by definition technical in nature. The design guideline knowledge of the EHS professional is relied upon heavily during this portion of the review. These include clearances, electrical requirements, mechanical/thermal guarding, labeling, life safety, etc. An EHS checklist also verifies operation and maintenance specs for field service engineers and Owner personnel.

Issues that arise from the contracting trades are typically handled within the Functional Area Team (FAT). FATs are strategic teams that meet weekly to ensure the installation of process equipment is installed correctly and according to schedule. Tool owners, installation construction managers, EHS staff and the trades involved with the installation are tasked with identifying issues involved in the installation ahead of time to prevent issues in the field.

Appendix 16: Power Generator Case Study Survey Data

Power Company Survey Results

ID	Question 1(Heard of DfCS?)					Question 2(Attitude towards DfCS)			
	Never heard	Heard but Org. never considered implementing	Org. considered implementing but has never done	Org. has been involved with it on ltd. basis	Org. routinely ensures DfCS on projects	DfCS benefits do not seem compelling	DfCS benefits sound promising but barriers present	Will consider trying DfCS	Will implement DfCS
1				1					1
2	1							1	
3					1				1
4					1				1
5					1				1
6					1				1
7					1				1
8	1							1	
9					1				1
10					1				1
11	1								1
12				1				1	
Total	3	0	0	2	7	0	0	3	9
Average									
Percent	0.25	0.00	0.00	0.17	0.58	0.00	0.00	0.25	0.75

Power Comp

ID	Question 3(Resources/ processes used to address CWSH)						
	CWS part of A/E scope per contract	Design checklists	Constructability reviews	In-house design guides	Computer program	Other	No specific processes/ resources
1		1	1	1			
2		1	1	1	1		
3		1		1			
4		1	1	1			
5	1	1	1	1	1	Computer	
6	1	1	1	1			
7		1	1				
8		1	1	1	1	Computer	
9	1	1	1	1	1	Computer	
10	1	1	1	1			
11	1	1	1	1			
12		1	1				
Total	5	12	11	10	4		0
Average							
Percent							

Power Comp

ID	Question 4(Importance of DfCS to CWSH)					
	Not at all important	Less important	About the same importance	More important	Significantly more important	I don't know
1		1				
2			1			
3			1			
4			1			
5			1			
6			1			
7			1			
8			1			
9				1		
10			1			
11			1			
12			1			
Total	0	1	10	1	0	0
Average						
Percent	0.00	0.08	0.83	0.08	0.00	0.00

Power Comp

ID	Question 5(Motivation to implement DfCS)							
	Competitive advantage	Improved CWSH	Improved facility OSH	Improved quality fo construction	Enhanced organization reputation	Reduced project costs	Shorter project schedules	Other
1		1	1	1	1	1	1	
2		1	1		1			
3	1	1	1	1		1		
4	1	1	1	1	1	1		
5		1	1	1				
6		1	1	1		1		
7		1	1	1	1	1	1	
8		1		1		1		
9		1	1	1	1	1	1	
10	1	1	1	1	1	1	1	
11		1	1	1	1	1	1	
12			1			1	1	
Total	3	11	11	10	7	10	6	0
Average								
Percent								

Power Comp

ID	Question 6 (Barriers to DfCS)
	Barriers to implementing DfCS on organization's projects
1	Lack of communication early in project development between design and construction
2	Legal ramification
3	Knowing how to implement DfCS appears challenging because design shows end product, how to get to the end product is mostly in
4	To remove the energy that may set condition in motion
5	Time and complacency
6	None
7	Getting everybody in design aware of & familiar with the database
8	Having the upfront information from construction in order to implement into design. The design schedule is already pretty pressed,
9	Change the culture so everyone in on board with DfCS or DfS
10	No barriers
11	No barriers
12	Project schedule
Total	
Average	
Percent	

Power Comp

ID	Question 7(Typical contract clauses hinder DfCS?)			
	Company's contract wont change regarding A/Es DfCS ideas	Company's contracts could be changed regarding A/Es DfCS ideas	Company's contracts would be easily modified regarding DfCS ideas	Not Necessary to change company's contract
1			1	
2	Answered don't know			
3				
4				1
5			1	
6	NA			
7	NA			
8	NA			
9				1
10				1
11	No answer			
12	No answer			
Total	0	0	2	3
Average				
Percent	0.00	0.00	0.40	0.60

Power Comp

ID	Question 8(Support modifications to standard A/E contract documents?)				
	Yes	Yes, if no impact on other roles and responsibilities of A/E on a project	Yes, if no impact on Org. roles and responsibilities on a project	No, would not support modifications to the standard contract documents	Not familiar with standard contract documents
1	1				
2					1
3					
4			1		
5					1
6	NA				
7	NA				
8	NA				
9	1				
10			1		
11	No answer				
12	No answer				
Total	2	0	2	0	2
Average					
Percent	0.33	0.00	0.33	0.00	0.33

Power Comp

ID	Question 9(A/E resistance as barrier to DfCS?)				Question 10(A/Es capable of performing DfCS)				
	A/Es will never agree and Org. cannot force	A/Es will resist, but Org. can insist the A/Es	Some A/Es will agree, some will disagree	Most of A/Es will gladly perform DfCS	Most A/Es could never learn enough	Most A/Es could learn enough	Most A/Es could perform DfCS using assistance	Most A/Es could easily learn	Most A/Es already capable
1			1				1		
2				1					1
3				1				1	
4				1				1	
5			1				1		
6				1				1	
7				1				1	
8				1			1		
9			1				1		
10				1				1	
11				1					1
12			1				1		
Total	0	0	4	8	0	0	5	5	2
Average									
Percent	0.00	0.00	0.33	0.67	0.00	0.00	0.42	0.42	0.17

Power Comp

ID	estion 11(% more in design f	Question 12(Increase in A/E fees a barrier?)				Question 13(Liability of Org	
	Upto _% more in design fees to perform DfCS	DfCs will never happen due to increased fees by A/Es	Higher design fees could become acceptable	Increased design fees could be justified to higher management	No or modest increase in fees by A/Es	will increase liability exposure	will not affect liabililty exposure
1	1%			1		1	
2	No answer	1				1	
3							
4	No answer			1			
5	No answer			1			
6	0%				1		NA
7	NA	NA					NA
8	25%		1				1
9	1%				1		No answer
10	0%				1		
11	No answer	No answer					No answer
12	No answer	No answer					No answer
Total		1	1	3	3	2	1
Average							
Percent		0.13	0.13	0.38	0.38	0.33	0.17

Power Comp

ID	. w.r.t DfCS)	Question 14(Reasons for non-implementation of DfCS)						
	decrease liability exposure	Not applicable	Too costly	Added design duration	No perceived benefit	Not enough information/ knowledge about DfCS	Higher priority for other project objectives	Other
1			1	1			1	Safety could be
2		1						
3		1				1		
4	1							Budget &
5	1	No answer						
6		1						
7		1						
8			1				1	
9		1						
10	1	1						
11		1						
12		No answer						
Total	3	7	2	1	0	1	2	0
Average								
Percent	0.50	0.54	0.15	0.08	0.00	0.08	0.15	0.00

Power Comp

ID	Question 15(Org.'s priority criteria w.r.t construction projects)							
	Aesthetics	Construction worker safety & health	Facility user safety & health	Maintenance worker safety & health	Project cost	Project schedule	Quality of final product	Other
1	5	1	1	1	4	3	2	
2	7	1	2	3	4	6	5	
3								All of the above
4	No answer	1	1	1	3	4	2	
5	2	1	1	1	1	1	1	
6	7	2	3	4	1	5	4	
7	7	1	3	2	5	6	4	
8	7	3	1	2	5	4	6	
9	7	1	2	3	6	4	5	
10	7	1	3	2	4	5	6	
11	8	3	2	1	7	6	5	4(Reliability)
12	7	3	1	2	5	4	6	
Total								
Average	6.40	1.64	1.82	2.00	4.09	4.36	4.18	
Percent								

Power Comp

ID	Question 16 (Change in the following items as a result of DfCS)										
	Construction injuries				Design costs				Construction costs		
	Decrease	No change	Increase	I don't know	Decrease	No change	Increase	I don't know	Decrease	No change	Increase
1	1						1				1
2	1						1				1
3	1						1				1
4	1						1				1
5	1						1				1
6	1				1				1		
7	1					1			1		
8	1						1			1	
9	1					1			1		
10	1					1				1	
11	1						1				1
12	1						1			1	
Total	12	0	0	0	1	3	8	0	3	3	6
Average											
Percent	1.00	0.00	0.00	0.00	0.08	0.25	0.67	0.00	0.25	0.25	0.50

Power Comp

ID		Question 16 (Change in the following items as a result of DfCS)										
		Total project costs to the owner				Design durations				Construction durations		
	I don't know	Decrease	No change	Increase	I don't know	Decrease	No change	Increase	I don't know	Decrease	No change	Increase
1				1				1			1	
2				1				1			1	
3					1		1				1	
4				1				1				1
5				1				1				1
6		1					1				1	
7		1					1				1	
8				1				1			1	
9		1					1			1		
10			1				1				1	
11		1						1				1
12			1					1				1
Total	0	4	2	5	1	0	5	7	0	1	7	4
Average												
Percent	0.00	0.33	0.17	0.42	0.08	0.00	0.42	0.58	0.00	0.08	0.58	0.33

Power Comp

ID		Question 16 (Change in the following items as a result of DfCS)										
		Total design and construction durations				Construction quality				Number of lawsuits against o		
	I don't know	Decrease	No change	Increase	I don't know	Decrease	No change	Increase	I don't know	Decrease	No change	Increase
1				1			1					1
2				1			1					1
3			1					1				
4			1					1		1		
5				1			1			1		
6			1					1		1		
7			1					1		1		
8				1				1		1		
9			1					1			1	
10			1					1		1		
11				1				1		1		
12				1			1				1	
Total	0	0	6	6	0	0	4	8	0	7	2	2
Average												
Percent	0.00	0.00	0.50	0.50	0.00	0.00	0.33	0.67	0.00	0.58	0.17	0.17

Power Comp

ID		Question 16 (Change in the following items as a result of DfCS)							
	wners	Number of lawsuits against A/Es				Reputation of A/Es within society			
	I don't know	Decrease	No change	Increase	I don't know	Decrease	No change	Increase	I don't know
1				1			1		
2				1				1	
3	1				1				1
4		1						1	
5		1						1	
6		1					1		
7		1						1	
8		1						1	
9			1					1	
10		1						1	
11		1						1	
12			1				1		
Total	1	7	2	2	1	0	3	8	1
Average									
Percent	0.08	0.58	0.17	0.17	0.08	0.00	0.25	0.67	0.08

Power Comp

ID	Question 17
	Changes made or needed to Org. structure &/or project development process
1	None
2	Don’t know
3	The organizational structure and/ or project development process should not change when implementing DfCS program
4	We are implementing DfCS on projects
5	No answer
6	Already implemented
7	Made design personel aware of the database & implemented DfCS checklist
8	More upfront co-ordination with construction management & more information needed on specific construction schedule needed early
9	Start DfCS audits, encourage all leaders to perform their DfCS tasks completely. Some people will do just enough to say they considered
10	None
11	I have worked at SCS for anout 5 years and SCS has always stressed safety in all aspects of the design and construction process since I
12	No answer
Total	
Average	
Percent	

Power Comp

ID	Question 18
	What would enable or assist DfCS on Org. projects
1	Communication/ dialogue early in the project design phase with construction management
2	Don’t know
3	
4	No answer
5	No answer
6	Already implemented
7	NA
8	Upper management would have to buy in on this in order to incorporate this program because it would be very different schedule than
9	See answer to 17 and John Gambatese's recommendations for improvement to the our firm.
10	Nothing
11	No answer
12	No answer
Total	
Average	
Percent	

Appendix 17: Power Generator Case Study Interview Compilation

Note: All identifying firm, plant and individual person names have been disguised. The name of the case study firm will be denoted as PG.

Drivers

Who is the primary driver of DfCS on this project or your company's projects in general?

(Owner – Design Mngr.): PG. Contractors pushing it too, but mostly not DfS.

(Owner – Mechanical Design): PG, Engineering Manager (individual name) started it.

(Owner – Electrical Design): PG, (individual formally tasked with initiating DfCS). Top-down implementation. In 2000, it used to be "Cost, Schedule, Quality." Now it is "Cost, Schedule, Quality, and Safety."

Owner – Electrical Design Supervisor: (plant name) was first DfS project. Initiated by individual formally tasked with initiating DfCS in civil group but it was part of overall company initiative.

(Owner – Project Mngr.): PG – Design office.

(Owner – Civil Design): Design Leads within PG. (Civil, Mechanical, Electrical, I&C).

(Construction – Discipline Leads): PG, Engineering Design. (individual name) – Construction rep. on DfS process.

(Owner-Safety) : (individual name), Assistant Site Manager.Owner – I&C Design: Design group manager (individual name). Top management bought into quickly.

Concrete and Site Engineering: Top management.

What do you think is their primary motivation for pursuing DfCS?

(Owner – Design Mngr.): Eliminate injuries. Safe projects. "We do not want unsafe plants or sites." It is part of the company's efforts to eliminate injuries and create safer work environments, both in the office and in the field.. It is the right thing to do.

(Owner – Mechanical Design): Target Zero program. Long time since last large PG project; strengthening of safety program because of long time between projects.

(Owner – Electrical Design): Safety. Fit well within Target Zero program, which was management's reaction to several deaths on site. Management said, "This is not acceptable." It is Design's way to play a role in the Target Zero program.

Owner – Electrical Design Supervisor: Improve safety of finished product. "We live our designs every day. We design for use, maintenance and construction."

(Owner – Project Mngr.): Safety and monetary.

(Owner – Civil Design): Construction safety, as part of Target Zero safety program. Modularization and cost.

(Construction – Discipline Leads): Eliminate risk. Facilitate Target Zero program. Engineering's contribution to Target Zero. Prefer to remove hazard instead of protect employee from the hazard.

(Owner-Safety): Designing in safety can make processes quicker and safer.

Owner – I&C Design: Target zero was being initiated this was perceived to make a big contribution.

Concrete and Site Engineering: Corporate responsibility. Safety is a core value underlying all processes.

What is your individual primary motivation for participating in DfCS?

(Owner – Design Mngr.): Safer projects.

(Owner – Mechanical Design): Safety (personal and external). Responsibility and authority rests at the Design Tech level, which creates accountability and caring for safety in design. Design and Tech leads are evaluated based on DfS. "I won't design or build anything that could get somebody hurt. Noone wants to carry that on their conscience." "And I don't want to go on an unsafe facility." "I report anything unsafe, even if it is not related to design or construction."

(Owner – Electrical Design): Safety. Get on-board to make sure headed in same direction. They have become increasingly aware of how safety needs to pervade everything they do, including at home. Safety used to be part of quality, but now it is a stand alone issue.

Owner – Electrical Design Supervisor: He wants people at plant to be able to go home each night to their families. The (NEC) code is good in some areas but they need to exceed Code in some areas and DfS is a way to design out hazards.

(Owner – Project Mngr.): Safety.

(Owner – Civil Design): Safety. Same as PG.

(Construction – Discipline Leads): Remove hazards to construction workers. Contribute to the overall goals of the PG.

(Owner-Safety): (they are not involved in identifying DfCS)

Owner – I&C Design: They were already doing it but the program formalized it.

Concrete and Site Engineering: It is right thing to do. Efficient design is going to be safe.

Would DfCS have been implemented if the primary driver was not interested in it?

(Owner – Design Mngr.): No. If PG didn't demand DfS and proactive site management, some contractors would focus on getting in and out of the site and maximizing profits.

(Owner – Mechanical Design): 'Yes, because we are own boss.' They have responsibility and autonomy. So they do not wait to be told to do something that should be done.

(Owner – Electrical Design): Not emphasized as much; less attention; less formalized.

(Owner – Project Mngr.): Yes. Business drivers would have made it happen.

(Owner – Civil Design): Yes. Overall safety, and lowering cost. Safety is a large part of the culture at PG. Safety is included in yearly bonuses.

(Construction – Discipline Leads): More informal process (as was done before DfS also).

(Owner-Safety): Some obvious changes would have occurred regardless.

Owner – I&C Design: They have always done it.

Concrete and Site Engineering: Yes, through constructability review. Liability is not an issue in his industry.

Processes

What did PG. do initially to initiate and enable DfCS?

(Owner – Design Mngr.): PG used to say that construction safety was the contractors' business. But they decided they would not hire contractors with bad safety records.

(Owner – Mechanical Design): Set up design for safety group, which produced checklists and ensured they were used. "Made an auditable trail."

(Owner – Electrical Design): Quarterly safety meetings, which focused on issued related to design. Paula formed the DfS Committee, then came checklists.

Owner – Electrical Design Supervisor: Announced DfS initiative, then convened people from different groups.

(Owner – Project Mngr.): Safety performance initially poor, and something needed to change. Engaged in CII along with recommendations from university professors.

(Owner – Civil Design): Companies contributing to DfS database.

(Construction – Discipline Leads): Not known. Maybe checklists developed.

(Owner-Safety): (individual name) came to Birmingham office to plan the project, including site layout issues. There was a fiberglass area and electrical lines that needed to be moved.

Owner – I&C Design: They held meetings that led to checklists and a database.

Concrete and Site Engineering: Safety was made an explicit core value that drove major construction projects in their big environmental building program.

How do DfCS opportunities get identified?

(Owner – Electrical Design): Design Lead spending time at the site; talking with field staff; phone call from construction site. Lessons learned program. "When a project is starting, I sit down informally with electrical lead construction person to get to know each other and talk about how we want to do things on this project." "Informal communication between design and construction has gone on for years because each plant has a permanent engineer who knows operations and maintenance issues.

Owner – Electrical Design Supervisor: Upfront meetings. Checklists are important but need to be reviewed for updating given new plant and construction technology.

(Owner – Mechanical Design): They do constructability and operability reviews of designs, which should affect construction safety. They interact with construction group personnel, not directly with contractors. Monthly DfS Committee meetings analyze incidents.

(Owner – Project Mngr.): 3-D model reviews. Engineering/construction/operations personnel review the models. Checklists at 20-25% of the design.

(Owner – Civil Design): Team meetings. Input from those constructing it. HICC for each project.

(Construction – Discipline Leads): Series of meetings with design team; constructability reviews. Lessons learned meetings at the end of other projects provided ideas for this project.

(Owner-Safety): (individual name arrived on site during the project foundations.) There were monthly review meetings with the design leads and site personnel and safety personnel, including (individual name) and (individual name).

Owner – I&C Design: Meetings and checklists and databases are used.

Concrete and Site Engineering: Checklists were developed. (He was formally with (name of other engineering firm), which had a less formal DfS program.)

How are DfCS design decisions made? Who makes them and how are meetings, emails or phone conversations used?

(Owner – Electrical Design): Construction Services (CS) usually wins over Engineering if there is a difference of opinions. Easy to make decisions if cost and schedule are not factors. Construction has 90% of project budget while design only has 10% of budget.

Owner – Electrical Design Supervisor: F2F meetings, site walks where equipment is to be installed ("walk down") to make decisions about site layout, crane picks. Design modeling includes construction equipment.

(Owner – Mechanical Design): Construction personnel are part of conceptual review. They can identify crane set up locations and models needed.

(Owner – Civil Design): Low cost issues are done right away. Larger cost issues must be approved by the Project Manager. If "safety" is attached, then it is typically approved.

(Construction – Discipline Leads): Design team lead makes the decisions. Communicated by e-mail, design change notice, phone call, or just appears on the drawings if a small change.

(Owner-Safety): All of the above.

Owner – I&C Design: Model reviews and early design meetings. Emails and phone calls, including during construction. Checklists and focus areas grow as project progresses. They have a candid culture.

Concrete and Site Engineering: Design leads meet at the beginning of a project to review project-specific DfS checklists. The database has been developed over the past five years.

What is the form and content of DfCS information that is communicated?

(Owner – Electrical Design): Safety talks now part of all meetings. If major costs are involved, then there is a process to get approval. But most decisions are implemented without formal documentation and approval. Sometimes changed processes are documented in a lessons learned file or design database.

Owner – Electrical Design Supervisor: Working now to create and implement lessons learned.

(Owner – Mechanical Design): They don't always know how contractor will build something. Construction group will bid out to ~ 5 bidders on a short list. Sometimes turnkey contracts are outsourced.

(Owner – Civil Design): Checklists and model reviews.

(Construction – Discipline Leads): E-mail, design change notice.

(Owner-Safety): Modeling.

Owner – I&C Design: Video conferences, photos, site visits.

Concrete and Site Engineering: During the internal design reviews, Navisworks is used for reviewing 3 models each month. Safety is part of the discussions. Safety and construction personnel review models with project engineer and plant group (user). Maintenance access is discussed with plant group. Constructability is discussed with construction group, including crane picks discussed at conceptual phase.

What phases of construction have had stronger DfCS consideration? Why?

(Owner – Design Mngr.): Applied to all disciplines. No difference. Start at conceptual design. Better to start earlier.

(Owner – Mechanical Design): Good for all disciplines. Same reduction of risk. No more or fewer items to be added to the checklists for each discipline. All have been developed to the same level to date.

(Owner – Electrical Design): More in civil. Electrical is already bound by National Electrical Code and National Electrical Safety Code. Best to do DfS upfront in the design process.

(Owner – Project Mngr.): Early on in the DfS history, good ideas in electrical; stamped out many design issues in Electrical, so now not as much new material. Still getting many in civil/structural.

(Owner – Civil Design): Within civil, no difference. Mostly access questions for structural steel. Good all along. More attention in detailed design. Easier in detailed design (more detail is available).

(Construction – Discipline Leads): Earlier is better. Ductwork and steel is biggest risk. All need to be looked at equally. Accessibility is big.

(Owner-Safety): Can't tell.

Concrete and Site Engineering: Civil gets a lot of attention but all phases are included. Civil does conceptual support of excavation design then includes detailed design by contractor who designs or hires out to more local prime site contractor.

Owner – I&C Design: All phases equal but INC are on site longer and more often than other disciplines. INC has fall issues too, so they will pass on civil-type issues and solutions to other groups.

What DfCS-related information was initially possessed by each of the following entities? What about now?

PG. capital projects staff

(Owner – Design Mngr.): Most DfS input.

(Owner – Electrical Design): Not much input. Checklists really help now. Electrical field services provide them with good information about electrical hazards but do not provide DfS suggestions for reducing them.

(Owner – Mechanical Design): (individual name) had experience with safety issues while designing a retrofit for a fine paper plant while with a different employer.

(Owner – Project Mngr.): Early on lots of input. Plant Operations also provide lots of input on user safety because they have to live with it.

(Owner – Civil Design): Much from design group.

(Construction – Discipline Leads): Depends on experience.

Owner – I&C Design: Lots.

Design professionals

(Owner – Design Mngr.): Hired consultants must follow DfS program as it is stipulated in their contract. No much DfS input. PG uses (firm name) and (firm name) and requires them to use PG checklists. (firm name) is a big firm with their own ways of doing things, but PG reviews all designs. Outside firms do not resist because the power industry is very safety oriented, although smaller firms may be less so.

(Owner – Electrical Design): Fair amount; good ideas.

Owner – Electrical Design Supervisor: There are ~90 people in electrical group, which includes ~ half "supplemental workers." They sometimes outsource to (firm name) who didn't do SbD at first because PG had not written good RFP and contracts. But now (firm name) is doing SbD for both construction and maintenance.

(Owner – Project Mngr.): Less input. Consultants not used often by PG.

(Owner – Civil Design): Not typically involved in general design of PG.

(Owner-Safety): There was outside engineering on the project. All Design-Build contractors should have had DfCS in their contracts.

Owner – I&C Design: The outside AE firms they use have similar programs, but they do not know what the contract requires.

Concrete and Site Engineering: Everybody is attuned to safety. Site and trades personnel volunteer all kinds of ideas for making safer designs through the construction group. This occurs through established processes and happens regularly throughout the design life cycle. Three areas: design, plant, construction.

GC/CM

(Owner – Design Mngr.): Not usually under contract during design.

(Owner – Electrical Design): Not as much as trade contractors.

Owner – Electrical Design Supervisor: PG used to have their own construction staff but now play role of CM and hire prime contractors, who bring in their own subs. Lately PG has contracted with electrical prime directly. Primes manage safety of all crews on site.

(Owner – Project Mngr.): Lots of input now

(Owner – Civil Design): Good source of info (PG employees). Site experience helps.

(Construction – Discipline Leads): Have the most to contribute.

Owner – I&C Design: They use (firm name), (firm name) and small local firms. PG encourages feedback once a firm gets involved.

trade partners

(Owner – Design Mngr.): Not typically involved in DfS. But PG does include DfS issues in their specs for vendors.

(Owner – Electrical Design): Electrical field services provide a good amount. People in the field are generally helpful.

Owner – Electrical Design Supervisor: They give detailed specs to vendors like GE that ensure quality and safety.

(Owner – Project Mngr.): Lots of input now.

(Owner – Civil Design): Lots of input. Safety record reviewed when hired.

(Construction – Discipline Leads): Yes, lots. Curing construction, the RFI and Field Change Process is used.

Owner – I&C Design: (PG dictates what INC equipment is used.)

Barriers/Enablers/Impacts

How is safety addressed relative to other priorities such as cost, schedule, and quality?

(Owner – Design Mngr.): Safety always on top. Other priorities not considered. They couldn't focus too much on maximizing profits even if they wanted to because the Public Utility Commission caps their profits. Public utility (not for profit) mostly concerned about safety. Commercial market focus more on profits. Some subs cut their fees to nothing to get commercial projects, which makes it harder for them to implement Dfs.

(Owner – Mechanical Design): Safety is a high priority. Everything is a factor and all ought to be equally considered.

(Owner – Electrical Design): Ten years ago safety was #4 on the list; now it is #1. Safety wins unless a change would really impact cost or time. Process in place to assess cost/schedule; requires PM approval. Example: Pipe hammering issue where bypass was installed even though it was a high cost.

Owner – Electrical Design Supervisor: They truly try to balance this is tough to do. They look for technology that allows safety without increasing cost too much. They sometimes have to fight

to prevent spacing equipment too closely, which affects both construction and maintenance safety.

(Owner – Project Mngr.): If item is identified as a safety improvement, it is always done. Cost is not a concern.

(Owner – Civil Design): Safety always wins. Recognized lower cost in long-term (higher cost upfront).

(Construction – Discipline Leads): Depends on the level of risk. Safety is #1 and always takes priority. If it says "safety", it will be approved.

(Owner-Safety): Safety management personnel were not involved until after the design was done. But (individual name) or (individual name) were involved during the review.

Owner – I&C Design: Safety is first and will not be compromised. But try to make sure safety solutions are cost-effective and reasonable and on schedule.

Concrete and Site Engineering: Efficient design is constructable and safer so there is never a problem balancing them. They put more details on drawings for clarity. Sometimes erection drawings are included in plans. They spend a lot of time identifying and showing underground lines and hazards on plans. They use remote sensing (ground penetrating radar) during the concept stage then vacuum excavation during construction.

What do you feel are the most important barriers to implementing DfCS on your organization's projects?

(Owner – Electrical Design): None. Need to train designers. Need designers who are willing/open to participants.

Owner – Electrical Design Supervisor: They need to keep up with technology that can help safety. They need to make sure Lessons Learned do not become wish lists.

(Owner – Project Mngr.): None. Folks are on-board. Old database hard to navigate, but the new database is good now.

(Owner – Civil Design): New employees need to be aware of checklist and database. Buy-in from Project Management. Need time in schedule.

(Construction – Discipline Leads): Liability: need more extensive engineering review; if giving contractor work direction; and prescribing work sequence.

(Owner-Safety): As long as construction personnel or construction safety personnel are involved with reviewing the design, it is OK if the the actual project safety personnel are not involved during the design.

Owner – I&C Design: Models help them resolve cost and safety issues. Told story about moving fans to where they could be more easily maintained. It required additional cost, including for platforms, but it helped construction safety because it reduced construction duration. What changes to your organization's structure and/or project development process were made, or would be needed, in order to implement DfCS on projects?

(Owner – Project Mngr.): Project meetings during design. DfS milestones were added to the project development process. No other changes to the project development process.

(Owner – Electrical Design): No changes are needed. Checklists are truly used.

(Owner – Civil Design): Checklists and database are new now. Lessons learned meetings.

(Owner-Safety): Alan: It would be good to have safety people with prior similar projects experience involved during design.

(Owner – Mechanical Design): DfS feedback often comes to MechEs through short, informal phone calls between the field and lead engineers. They need to document these calls better as CivE has done.

Concrete and Site Engineering: Nothing needed.

What would enable or assist your organization in implementing DfCS on your organization's projects?

(Owner – Electrical Design): Weakest link not enough time and project budget to utilize and review the database.

(Owner – Project Mngr.): Database very helpful.

(Owner – Civil Design): Working well now.

(Owner – Mechanical Design): If we are to address DfS better, engineering needs to have more direct communication with contractors, including feedback from contractors about things contractors do not like that design does. Contractors know their trade best.

(Owner-Safety): Site safety personnel go through construction to design, which is fine.

Owner – I&C Design: They would score the DfS program as 8/10. They need to expand DfS outside design, such as for the fleet. They need to keep focused on DfC and not get complacent. People at all levels need to feel empowered and valued.

Concrete and Site Engineering: Nothing needed. There is less budget pressure here than there was at Rust.

What have been, or do you foresee will be, the impacts of implementing DfCS?

(Owner – Design Mngr.): It has changed their culture. His boss has never pushed him to reduce DfS expenses.

(Owner – Mechanical Design): Awareness of safety issues in design phase.

(Owner – Electrical Design): Safety. Additional upfront cost. Difficult to measure to measure; more positive than negative. More interaction between design team. More interchange of ideas between all stakeholders. "The DfS program has led to good DfS practices being implemented without needing to think about them on future projects.

(Owner – Project Mngr.): Safety. Lower cost, but not an issue. Change in mindset; shift in philosophy; different design culture, which is management supported.

(Owner – Civil Design): Designers more aware of safety. Good quality contractors bidding on projects because they are safer. Better safety. Lower cost due to modularization.

(Construction – Discipline Leads): Communication amongst project team members. Communicate to new employees, and to out-sourced services. Highly developed existing safety program. Dependent on Project Manager's motivation for the process.

(Owner – I&C Design): Improved safety. Different designs. Improved productivity.

(Owner – Project Engineer): Improvements in constructability, safety, and access for equipment and maintenance personnel. Less construction cost. Impacts in the design office: more of an emphasis on safety; improved quality of design; a little more time to design; and a little more cost.

(Owner-Safety): Faster, safer construction. Maybe less cost too.

Project

How is this project different than typical DBB projects?

How have these differences affected the application of DfCS?

If you could start the project over, what DfCS-related thing would you differently?

(Owner – Mechanical Design): More and better documentation. More and direct involvement with construction team. More feedback from GC's on historical problems in design.

(Owner – Electrical Design): Not much. "I would have \put more effort into it. I wasn't sure if this program was going to stay."

(Owner – Project Mngr.): No changes; likes the program now.

(Owner – Civil Design): None. Good, manageable way to do it now.

(Construction – Discipline Leads): Nothing comes to mind.

Could the project DfCS processes work on all projects?

(Owner – Project Mngr.): Yes; need to apply with the right mentality; people and management must be on-board.

(Owner – Civil Design): Need less emphasis on cost.

To what extent does your permanent employer apply DfCS on other projects?

Other

(Owner – Design Mngr.): PG's RIR has decreased from about 3.0 to 0.95 in the past 5 years. The DfS safety program includes planned meetings and is part of the Target Zero program. The nature of injuries has changed: now more minor injuries and few major injuries. More investigation of incidents, both after accidents and near misses. More shop assembly; less number of injuries on the project site.

PG is a life cycle company. They design, build and operate for decades. They have designed their own plants since the 1930s. There are approximately 500 design employees.

PG is a CM but sometimes hires large firms such as (firm name) to be a prime . (firm name) self-performs a lot of work, but not electrical. (firm name) is sometimes hired as a labor broker then PG manages everything else. PG hires piling and foundation subs.

(Owner – Project Mngr.): Target Zero: Field safety efforts include daily safety meetings and other on-site efforts. DfS something to support Target Zero and a very big part of the program. Not much reported as design issues in incidents. At end of (plant name) Project, there was a long list of "to do" items and a bucket of money. All of the items labeled "safety" on the to-do list were funded. Design changes made for safety: recognized by the field; and carried from job-to-job at the request of the contractor.

(Owner – Mechanical Design): DfS program focus on O&M safety, which by default also improve construction safety. Designer connection is typically with the Construction Services group on site, not the contractor on site; this limits communication with those doing the work. PG typically uses a GC selected from a small list of approved GC's. Designers typically know how the work will be completed or have a general idea of the work sequence. Combination of contact/communication with Construction Services and the design knowledge of the designers: can this take the place of direct input/communication with the GC/trade contractors on the job in terms of getting DfS knowledge into the design? Labor broker situation creates more Design-labor interaction.

Alan: some plants are union while others are not. The (plant name) project had a labor broker, which allows more interaction between PG design and worker crews. But the labor crews do not do a construction review until a project starts.

(Owner – Electrical Design): Checklist is a good tool for "How to" questions. Should organize the checklist also according to design phase (e.g., conceptual design, detailed design, construction documents).

(Construction – Discipline Leads): DfS contributes less than 50% to the entire safety program. Other elements of the safety program affect safety to a greater extent. Feedback from trades in terms of the safety related to the design is both positive and negative. Improvement in the design is still needed.

(Owner – Project Engineer): What is needed for a DfS program to be successful: construction input and communication; customer (user) input and communication; and an emphasis within the engineering team that this is to be included in their design. DfS is more of a design program than a safety program.

(Owner-Safety): (individual name) (who started working at PG about 1.5 years ago) had had heard that the project had been DfS, but he hadn’t heard it was a formal program.

Appendix 18: Energy Company Case Study Survey Data

Energy Company Design for Construction Safety

Q1

Had you heard of Design for Construction Safety (DfCS) before this survey?

Answer Options	Response Percent	Response Count
I had never heard of DfCS.	67.6%	23
I had heard of DfCS but my organization has never considered implementing it.	2.9%	1
My organization has considered implementing DfCS but has never done so.	0.0%	0
My organization has been involved with DfCS on a limited basis.	14.7%	5
My organization routinely ensures DfCS occurs on our projects.	14.7%	5
answered question		34
skipped question		0

2

Which statement best matches your overall attitude toward the DfCS concept?

Answer Options	Response Percent	Response Count
The potential benefits of DfCS do not seem compelling to me.	0.0%	0
The benefits of DfCS sound promising but there are too many barriers to try	2.9%	1
The benefits of DfCS sound like a good idea. I would consider trying it.	58.8%	20
DfCS sounds like a winner. I have already or will likely try to implement it	38.2%	13
answered question		34
skipped question		0

3

If your organization formally addresses construction worker safety and health in the design of its projects, what

Answer Options	Response Percent	Response Count
Construction worker safety is part of the architect-engineer (A/E) scope of work per	34.4%	11
Design checklists	59.4%	19
Constructability reviews	81.3%	26
In-house design guides	59.4%	19
Computer program	15.6%	5
No specific process/resources	6.3%	2
Other (please specify)	6.3%	2
answered question		32
skipped question		2

4

If your organization implements DfCS on projects, how important is DfCS to construction worker safety and

Answer Options	Response Percent	Response Count
Not at all important	0.0%	0
Less important	0.0%	0
About the same importance	50.0%	16
More important	15.6%	5
Significantly more important	6.3%	2
I don't know	28.1%	9
answered question		32
skipped question		2

5

What motivates, or would motivate, your organization to implement DfCS on its projects? Please check all that

Answer Options	Response Percent	Response Count
Competitive advantage	39.4%	13
Improved construction worker safety and health	97.0%	32
Improved facility occupant safety and health	75.8%	25
Improved quality of construction	60.6%	20
Enhanced organization reputation	69.7%	23
Reduced project cost	57.6%	19
Shorter project schedules	54.5%	18
Other (please specify)	0.0%	0
answered question		33
skipped question		1

6

What do you feel are the most important barriers to implementing DfCS on your organization's

Answer Options	Response Count
	17
answered question	17
skipped question	17

1 Lack of knowledge and overall strategy for implementation
2 The company already strives for safety and no LTA (Lost Time Accident) at all stages of project from conceptual studies, through detail design, through construction and overall executi
3
4 Existing programs for safety and human factors design
5 Projects are extremley large, very challenging, and in many cases in remote locations
6
7 Can't think of any.
8 None if it proves useful
9 Not all people have the same understanding of the importance of DfCS
10 Finding time for someone to work on implementing the process into our existing systems and getting it rolled out to the organization; I perceive that once the expectation to use DFCS a
11 We are not the contractor, so we need to ensure that the contractors have DfCS as part of their processes.
12 Cost and Scheduling
13 Introducing DFCS early in the design process. The major design decisions are made early in the process.
14 Project schedule
15 We do not design the contractor does, we manage projects
16 Potential for increased cost, longer schedule, and increased interfaces.
17 None

7

Please place a check by the statement that best reflects how you feel about whether typical contract clauses

Answer Options	Response Percent	Response Count
The language in my company's typical design and construction contracts explicitly	0.0%	0
It would take a lot of work, but the typical language in my company's contracts that	6.7%	2
It would be easy to modify my company's typical contract language to allow AEs to	60.0%	18
It would not be necessary to change my company's typical contract language to allow	33.3%	10
answered question		30
skipped question		4

8

Would you support modifications to standard AE contract documents (i.e., those promulgated by the American

Answer Options	Response Percent	Response Count
Yes, I would support any modifications regarding DfCS.	6.1%	2
Yes, I would support modifications regarding DfCS if they did not impact other aspects	18.2%	6
Yes, I would support modifications regarding DfCS if they did not impact my	15.2%	5
No, I would not support modifications to the standard contract documents.	0.0%	0
I am not familiar with the standard contract documents.	60.6%	20
answered question		33
skipped question		1

9

Please place a check by the statement that best reflects how you feel about potential AE resistance as a barrier

Answer Options	Response Percent	Response Count
AEs will never agree to perform DfCS and my organization cannot force them to do it.	3.4%	1
AEs will resist, but my organization can insist the AEs we hire perform DfCS.	27.6%	8
Some AEs my organization uses will agree to perform DfCS while others will not.	17.2%	5
Most of the AEs my organization uses will gladly perform DfCS.	51.7%	15
answered question		29
skipped question		5

10

Please place a check by the statement that best reflects how you feel about whether AEs are capable of

Answer Options	Response Percent	Response Count
Most AEs could never learn enough to effectively perform DfCS.	0.0%	0
It would take a lot of effort, but most AEs could learn enough to effectively perform	0.0%	0
Most AEs could perform DfCS with assistance from others, e.g., construction	50.0%	14
Most AEs could easily learn enough to effectively perform DfCS.	32.1%	9
Most AEs are already capable of effectively performing DfCS.	17.9%	5
answered question		28
skipped question		6

11

If I was reasonably confident that DfCS would reduce my total project costs (design and

Answer Options	Response Count
	23
answered question	23
skipped question	11
1	30
2	2
3	0
4	10
5	2
6	2
7	0
8	15
9	5
10	1
11	10
12	10
13	20
14	10
15	1
16	5
17	2
18	5
19	5
20	1
21	10
22	2
23	30
	7.7

12

Please place a check by the statement that best reflects how you feel about whether potential increases in AE

Answer Options	Response Percent	Response Count
AEs would need to increase their fees so much to perform DfCS that it will never	0.0%	0
It would take a lot of work, but the higher design fees associated with AEs performing	10.3%	3
The increased design fees associated with DfCS could be justified to higher	62.1%	18
AEs would not need to increase their fees and/or the modest increases would not be a	27.6%	8
answered question		29
skipped question		5

13

Please place a check by the statement that best reflects your concerns about your organization's liability with

Answer Options	Response Percent	Response Count
I believe that addressing construction worker safety during design is likely to increase	9.7%	3
I believe that whether or not construction worker safety is addressed during design will	12.9%	4
I believe that addressing construction worker safety during design is likely to decrease	77.4%	24
answered question		31

skipped question	3

14

If your organization considered DfCS but decided not to implement it, what were the reasons for not

Answer Options	Response Percent	Response Count
Not applicable to my organization	59.1%	13
Too costly	0.0%	0
Added design duration	18.2%	4
No perceived benefit to my organization	0.0%	0
Not enough information or knowledge about DfCS	18.2%	4
Other project objectives had higher priority	9.1%	2
Other (please specify)	4.5%	1
answered question		22
skipped question		12

15

What priority does your organization place on the following criteria with respect to its construction projects? Please rank the criteria with 1 being the highest priority, 2 the second highest

Answer Options	#1 priority	#2 priority	#3 priority	#4 priority	#5 priority	#6 priority	#7 priority	Rating Average	Response Count
Aesthetics	1	0	1	0	0	0	26	6.64	28
Construction worker safety and health	10	7	10	0	2	2	0	2.45	31
Facility user safety and health	17	8	0	3	1	0	1	1.90	30
Maintenance worker safety and health	0	9	12	0	2	4	0	3.26	27
Project cost	2	1	2	9	7	7	0	4.39	28
Project schedule	1	2	1	10	7	7	1	4.55	29
Quality of the work	0	2	2	6	10	8	0	4.71	28
Other (please specify rank and criterion)									1
							answered question		31
							skipped question		3

16

If a substantial portion of the industry elected to perform DfCS on projects, how might the following items change? Please check one box in each

Answer Options	Decrease	No Change	Increase	I don't know	Response Count
Construction worker injuries	29	0	0	1	30
Design costs	2	4	22	1	29
Construction costs	11	7	9	2	29
Total project costs to the owner	5	11	9	3	28
Design durations	3	8	17	1	29
Construction durations	8	11	5	4	28
Total design and construction durations	2	13	7	5	27
Construction quality	1	8	19	0	28
The number of lawsuits against owners	20	7	0	1	28
The number of lawsuits against AEs	21	4	3	1	28
The reputation of AEs within society	1	3	21	3	28
			answered question		31
			skipped question		3

17

What changes to your organization's structure and/or project development process were made, or

Answer Options	Response Count
	9
answered question	9
skipped question	25

1 Need a process to be implemented and personell trained in application
2 Minimal
3 Nothing MajorThe company is very safety orientated
4
5 Minor changes to standard Bid Package and contract
6 Transfer of knowledge from experienced engineers to younger staff.
7 very little
8 Standard checklists, procedures or other guidance documents would need to be developed and added to our project management processes; development of a roll-out and training mo
9 No change.

18

What would enable or assist your organization in implementing DfCS on your organization's

Answer Options	Response Count
	8
answered question	8
skipped question	26

1 senior managment buy in to value proposition
2 Dedicated focus during the Constructabilioty Workshops that already take place.Include in Design Basis Documents when issued for tender
3
4 Demonstration that DfCS would be an improvement over existing programs
5 Would need to be implemented through the current project risk assessment methodology.
6 thorough review of cost/benefit
7 a dedicated resource to develop the tools above.
8 Senior management support.

Appendix 19: Energy Company Case Study Interview Compilation

Note: Firm name has been replaced with "EC".

Drivers

Who is the primary driver of designing for construction safety in your organization?

AA: He only knows of one engineering co-worker's interest in DfCS. He doesn't know why DfCS is coming through engineering rather than through the safety or construction groups.

BB: There is not a formal DfCS program. He looked at the EC Coordination Procedures document, which includes safety, but DfCS is not in there. He mentioned HazOps analysis during start up, which is DfCS but not for civil engineering. The Human Factors checklist is more for users. Civil could do more relating to this checklist. Heavy lifts on site get risk management but the nuts and bolts of design do not. EC does more in getting involved in design than 90% of other clients, but in the end design is the contractor's responsibility.

CC: EC does not have a formal DfCS program but EC is very safety focused. EC mgt emphasizes and is certainly committed to safety. EC is the leader according to safety statistics.

DD: Corp. HQ drives safety. (Incident) has driven loss management. Principles of the Operations Integrity Management System (OIMS) may include DfCS.

EE: Construction group have the most construction safety responsibilities. But it depends somewhat on how the project is classified. Sometimes EC owns the land and assumes all responsibilities. Sometimes an outside vendor assumes responsibility for prefab and assembly. Does EC have DfCS now? Their General/Global Practices help ensure a project will be safe for operations but not explicitly for construction. FEED = front end engineering design. During FEED they do not know what contractors will be involved. Later, contractors are chosen and they use their methods and equipment to achieve the highest efficiency. Example: Korean prefabrication yard builds decks upside down.

FF: Construction group drives safety but engineering group has responsibility for safety.

What do you think is their primary motivation for pursuing DfCS?

AA: It makes sense. There is a much higher emphasis on safety than his previous employers.

BB: EC spends tons of money and time to make project as safe as possible, and it is reflected in our safety statistics and drilled into employees every day. Management says "We care about everybody" but safety is good for business too. EC is the whipping boy so they need to not make themselves a target.

GG: EC does DfCS and uses integrated teams for life cycle safety, but does not have a formal DfCS program.

CC: The PC answer is we all want to be safe. Public relations is important. Lawsuit minimization is important.

EE: There is a strong correlation between quality and safety. If you pursue safety, quality is likely to result.

HH: EC is very different than other orgs we have probably interviewed. While there is no DfCS program per se, safety is such a dominant factor in everything and safety is probably the biggest factor the selection of contractors. I am critical of some EC programs but we do safety well.

FF: He saw opportunities for DfCS on (platform name). Last year EC did behavioral-based safety training but how to implement it? Safety at EC is low but it has plateaued. How improve it despite traditional focus on end user safety, cost, schedule, quality?

What is your primary motivation for participating in DfCS?

AA: Same as for EC overall.

BB: Safety is personal for him.

CC: I focus on performance of constructed facilities. I don't want to be associated with problems, such as failed structures.

DD: As a stockholder, he knows that lack of safety is too costly. The approach to DfCS should not be different from other safety approaches. Example, the Alaskan pipeline cost $8B and 31 lives.

EE: He thinks more about user safety than about construction safety. Told story about user falling through a railing system that had the rails spaced too wide. His boss called everyone in and talked about the safety importance of even small, non-structural items.

HH: His father was a construction worker who was debilitated due to a crush accident. His motivation for DfCS is that it is constructability, which is always good for getting a better product. He wants to be a part of EC's safety program.

Would DfCS have been implemented if the primary driver was not interested in it?

GG: It might have eventually resulted from the behavioral safety training they underwent with a consultant some time back.

CC: They try to design to a 2500 year earthquake, which equates to a 2% chance of problems over a 50 year life.

DD: Varies with individuals. Some would do it on their own.

HH: No because designers don't typically see how construction takes place. But EC does get design engineers out in the field.

FF: Their focus on constructability and interaction with construction and facilities people would cause some individuals to do it. It is showing up in pockets. Good to instill new ideas in new hires.

Processes

What did the primary safety driver do initially to initiate and enable DfCS?

BB: Safety doesn't just happen. It requires good planning. If you do it, it will help cost and schedule.

CC: Safety planning. EC philosophy is to design not to possibly fail. They design for both Type 1 risks (known probabilities) and Type II risks (unknown probabilities).

EE: Amount of prefab is not dictated by EC, it is chosen by the construction yard, which may be chosen by the design-builder. Location of the project is a strong influence. Construction specs given to design-builder may help DfCS.

HH: Not implemented yet. He can't recall any DfCS decision.

How do DfCS opportunities get identified?

BB: He recalls a European civil design firm who did a construction worker hazard analysis for each design element and changed the design where appropriate after getting construction input.

GG: Constructability reviews are programmed. EC Capital Projects Management System dictates gates, etc. These are both for cost-effectiveness/feasibility and for safety.

CC: He doesn't know regarding DfCS opportunities. But every major project gets fully analyzed. They hire high quality fabricators. Safety metrics are managed, which drives process planning.

DD: Part of other processes. Not explicitly done.

EE: Construction personnel will identify critical activities, such as major lifts, which may be given to the design team to address and resolve. There is one risk assessment performed per task. Present are representatives from the EC construction group, the EC engineering group (if there is a significant engineering component), DB contractor personnel. The DB may bring in a specialized sub.

HH: Heavy lifts are planned well, which include worker safety. Human Factors checklist deals with operations personnel but he thinks DfCS may be a by product. We have more gates and reviews than most firms.

FF: Each project has design reviews and constructability workshops. Items are identified and need to be stewarded and closed out. Focus is not only on DfCS opportunities. Example: large offshore lift. Risk assessments occur later in process and include identifying the risks before mitigators and the risks after mitigators. The latter need upper mgt approval.

How are DfCS decisions made? Who makes them and how are meetings, emails or phone conversations used?

BB: Construction personnel are involved in design reviews to some extent. But those reviews are for big picture items, not details. Our whole engineering, project management, construction, safety personnel go to design contractors' offices to perform a "cold eyes" review. There is also a EC team at all times at the design contractors' offices to review designs.

GG: Design reviews can last a week. Engineering managers, discipline leads, construction managers and leads, perhaps construction supervisors, design contractor, construction safety participate. Not much informal communication outside of those review meetings.

CC: All of their facilities must be fabricated and shipped to a (marine) site. EC focuses o getting this low risk, which requires them to get contractors involved in planning. I don't know if this affects safety or not. EC has world wide standards, which can be overdone.

HH: Human factors review is a part of design review stages, such as 30% design readiness review. May be part of other review but defined topic. May be informal or formal.

FF: Design reviews and construction workshops are face to face and last several days to a week. Project team presents it and "cold eyes" analyze it. There is informal communication too, depending on project personnel. They have a lot of senior technical advisors.

What is the form and content of DfCS information that is communicated?

BB: Loss Prevention Reviews do not focus on construction workers safety, just the start up and user safety.

GG: He knows action items need to be closed out but doesn't know if safety issues often are brought up.

EE: There may be informal conversations between project team members after the formal meeting. We are very good at addressing and closing engineering issues.

HH: Who is in the room during reviews? Project mgr, design leads as appropriate, DB or design contractor personnel, facilities design engineers.

FF: Specific technical issues.

What phases of construction have had DfCS consideration? Why?

GG: He doesn't know. Given the safety culture here, all phases probably get equal attention.

EE: The structural group is probably more attuned to safety issues than is the mechanical group, for example, because people can get killed by structures.

HH: None.

FF: Lifts get a lot of attention, as do non-mundane tasks.

What DfCS -related information was initially possessed by each of the following entities? What about now?

EE: Everybody brings something to the table because we are all specialists who bring value.

Owner

AA: They impose tremendous safety systems on their contractors, so DfCS could be successful.

GG: EC imposes their safety culture on all contractors.

EE: EC's systems are only half the story. You need trained and competent people. He knows the Human Factors checklist is used but hasn't seen it a lot.

HH: Good system for access, etc. Well designed facilities are safer. Their human factors spec goes into every design contract, but this checklist doesn't have much DfCS in it. EC brings to design teams a passion for safety. Most important thing they do is screen contractors.

FF: They have expertise across their projects. They have strong safety culture and are outspoken about it.

A/E

GG: Some of their EPC contractors have adopted EC's safety culture or bring their own safety culture and methods.

EE: Not much because they don't get to see construction.

HH: Not much.

FF: They typically also bring a lot to the table. Some have bought into safety cultures. Others have not but EC works to bring them up to speed, which causes these firms to start progressing on their own because they recognize the value.

GC/CM

GG: Probably bring more to table than the trades do.

EE: Their safety emphasis and processes vary with locations around the world. In U.S., they could help out a lot. I respect their opinions.

HH: Many GCs know about safety but not DfCS. He is not aware of GC or trade contractor participating in design reviews.

FF: They are generalists but still experts in process so they do bring a lot to the table from their work with other owners They repeat some processes a lot and see wider range of projects. Also some have own construction yards with prefabbing expertise.

trade partners

GG: May be tempted to cut corners on safety.

EE: They are most narrowly focused, not generalists. You need both. They need to focus on efficiency, which narrows them.

FF: They are not usually involved unless part of an EPC or they are part of a big lift.

Barriers/Enablers/Impacts

How is safety addressed relative to other priorities such as cost, schedule, and quality?

AA: Safety can be a show stopper. I think it can affect the selection of contractor, as happened with the selection of a geotechnical drilling firm. But EC starts off looking at cost and schedule.

GG: Safety is the number one priority. The oil industry has very strong risk analysis processes. Safety is the show stopper. Risk in cost and schedule can be accepted.

CC: Safety is given high priority. If I refused to do something unsafe, that would be OK.

DD: We estimate cost and schedule but not actual injuries.

EE: You can't separate them. If you have safety covered, you get the rest covered.

HH: It would be very rare where a human factors item would not be approved. If at design review a hazard is identified, you are expected to design it away. "List of points to be considered." It is up to the team to choose which to implement, but need to address each suggestion.

FF: On parallel with cost and schedule, perhaps #1. An accident will really mess up cost and schedule.

What do you feel are the most important barriers to implementing DfCS on your organization's projects?

AA: Lack of knowledge of the DfCS process. Once management says go, we will take it seriously. Cost won't be an issue if mgt is committed to it.

BB: We would have to get folks outside of engineering involved and committed. There is a VP of construction and a VP for EHS. We would have to get in our coordination processes. We would have to make design and construction more integrated.

GG: Minor barrier: Need to develop process that would be adopted by all. We all have our own ways of doing things.

CC: Bi barriers, but I am not sure if it would be effective. It may generate more paper, but will it be effective? Safety can be overdone.

DD: May already be part of OIMS. If you are bringing something new to table, something needs to move off the table. You could make it less safe for maintenance or the end product could be less reliable.

EE: Design contractors' limited construction knowledge. So he would try to ensure designers have field experience.

HH: SHE organization may have a NIH syndrome because they are proud of their program. Also, he is not sure how can EC move past the concept into the application?

FF: Resistance to additional process. We already have a lot of processes so we would need to incorporate into our existing processes, make it more explicit.

What changes to your organization's structure and/or project development process were made, or would be needed, in order to implement DfCS on projects?

AA: There are isolated pockets of construction knowledge. They are siloed between engineering and construction so more communication is needed. Will need checkpoint and checklists once training occurs. Training could be three ten-hour sessions.

BB: Need to change mindset on their own teams. Need to hold a 1-2 hour workshop to make sure we are all on the same page.

GG: No changes needed in structure or resources. We could accommodate that. He doesn't know how much human factors checklist is used.

CC: No changes needed. Do we have people with skills to make this happen? Do we have specialized expertise to have specialized entities perform DfCS?

DD: Perhaps changes needed in construction group.

EE: Nothing. We have the structure, people and job rotations needed.

HH: Would need to elevate human factors within the org. Right now, HF expert is brought in from a refinery each time human factors is to be reviewed.

FF: Just need to integrate into existing processes. Will need to expose existing personnel to concepts. Will not be huge endeavor.

What would enable or assist your organization in implementing DfCS on your organization's projects?

AA: Training. In the short term, DfCS could be a topic in weekly safety meeting to increase awareness.

CC: EC would have to promote this process within specialists. EC does not get contractor specialists involved early enough.

DD: Accident statistics that show a connection between design and safety. Is the problem real? Construction safety sounds good but perhaps it is not important for some projects.

EE: Nothing. He has people with needed field experience. Communication between engineering and construction and EHS is pretty good.

FF: Training for facilitators. General training on concept. (I asked about human factors checklist.) He doesn't recall much DfCS in it. There are other checklists.

What have been, or do you foresee will be, the impacts of implementing DfCS?

AA: Another layer of review. Construction injuries will decrease. Mgt won't allow cost and schedule to increase.

BB: The added cost, if any, would not be an issue if management believed safety would be improved.

GG: Less redesign needed due to constructability review flags. Less injuries.

CC: Contractors do know safety is important. Do we over do it?

EE: It could help their training goals. They are pretty good at not having silos but can always do better.

HH: All new processes add schedule and cost. But mgt knows this. Adding one more review will be a drop in the bucket because they already spend a lot of time and money on design reviews. Example: he will spend all next week doing a design review of one plant But DfCS could have a big impact on the industry overall.

FF: Improvement in overall safety performance, which will improve morale and public image and yield cost and schedule benefits after initial hiccups.

Are there any aspects of DfCS that we have not talked about that you feel should be discussed?

GG: Global Practices (which are reviewed every five years) requires that lessons learned be documented. There are formal processes for capturing lessons learned from key people. Most of the lessons learned involve contracting and money because EC is so safe, but a safety issue would definitely be included if one arose.

DD: We are bombarded by safety messages. Are we at the point of no increased benefits?

HH: Trying to do anything that crosses org boundaries takes real commitment because many of them are so focused on time and schedule.

Appendix 20: Industry Survey Data Compilation

Group	Question 1(Heard of DfCS?)					Question 2(Attitude towards DfCS)			
	Never heard	Heard but Org. never considered implementing	Org. considered implementing but has never done	Org. has been involved with it on ltd. basis	Org. routinely ensures DfCS on projects	DfCS benefits do not seem compelling	DfCS benefits sound promising but barriers present	Will consider trying DfCS	Will implement DfCS
Total CII	1	0	0	3	0	0	0	2	2
Total COAA	4	2	0	0	0	1	3	2	0
Total ASCE-CI	1	0	0	1	0	0	0	1	1
Total Federal	36	4	0	1	1	3	6	25	7
Total ODOT	8	0	0	1	2	0	0	7	4
Total PennDOT	34	1	0	2	0	1	2	31	3
Total	168	14	0	16	6	10	22	136	34
Percent of total	0.82	0.07	0.00	0.08	0.03	0.05	0.11	0.67	0.17

Group	Question 3(Resources/ processes used to address CWSH)						
	CWS part of A/E scope per contract	Design checklists	Constructability reviews	In-house design guides	Computer program	Other	No specific processes/ resources
Total CII	1	1	4	2	1	0	0
Total COAA	1	0	0	1	0	0	3
Total ASCE-CI	0	0	1	0	0	0	1
Total Federal	11	14	22	14	1	0	11
Total ODOT	3	3	7	6	0	0	2
Total PennDOT	6	10	30	14	2	0	8
Total	44	56	128	74	8		50
Percent of total	0.12	0.16	0.36	0.21	0.02		0.14

Group	Question 4(Importance of DfCS to CWSH)					
	Not at all important	Less important	About the same importance	More important	Significantly more important	I don't know
Total CII	0	2	2	0	0	0
Total COAA	3	1	0	0	0	0
Total ASCE-CI	0	0	1	0	0	0
Total Federal	0	5	18	1	1	16
Total ODOT	0	0	5	0	1	5
Total PennDOT	0	2	18	2	0	12
Total	6	20	88	6	4	66
Percent of total	0.03	0.11	0.46	0.03	0.02	0.35

Group	Question 5(Motivation to implement DfCS)							
	Competitive advantage	Improved CWSH	Improved facility OSH	Improved quality fo construction	Enhanced organization reputation	Reduced project costs	Shorter project schedules	Other
Total CII	4	4	2	4	4	3	3	0
Total COAA	1	3	2	2	1	3	2	0
Total ASCE-CI	0	2	2	2	1	2	0	0
Total Federal	6	35	30	23	15	19	14	0
Total ODOT	2	11	7	5	5	4	3	0
Total PennDOT	6	33	19	22	14	19	15	0
Total	38	176	124	116	80	100	74	
Percent of total	0.05	0.25	0.18	0.16	0.11	0.14	0.10	

Group	Question 7(Typical contract clauses hinder DfCS?)				Question 8(Support modifications to standard A/E contract documents?				
	Company's contract wont change regarding A/Es DfCS ideas	Company's contracts could be changed regarding A/Es DfCS ideas	Company's contracts would be easily modified regarding DfCS ideas	Not Necessary to change company's contract	Yes	Yes, if no impact on other roles and responsibilities of A/E on a project	Yes, if no impact on Org. roles and responsibilities on a project	No, would not support modifications to the standard contract documents	Not familiar with standard contract documents
Total CII	0	1	1	1	0	3	0	0	1
Total COAA	3	1	2	0	2	0	1	2	1
Total ASCE-CI	0	1	0	1	0	0	2	0	0
Total Federal	3	16	16	5	11	13	9	5	4
Total ODOT	0	1	7	3	5	2	1	0	2
Total PennDOT	0	12	15	8	12	6	8	0	11
Total	12	64	82	36	60	48	42	14	38
Percent of total	0.06	0.33	0.42	0.19	0.30	0.24	0.21	0.07	0.19

Group	Question 9(A/E resistance as barrier to DfCS?)				Question 10(A/Es capable of performing DfCS)				
	A/Es will never agree and Org. cannot force	A/Es will resist, but Org. can insist the A/Es	Some A/Es will agree, some will disagree	Most of A/Es will gladly perform DfCS	Most A/Es could never learn enough	Most A/Es could learn enough	Most A/Es could perform DfCS using assistance	Most A/Es could easily learn	Most A/Es already capable
Total CII	0	0	2	1	0	1	3	0	0
Total COAA	3	1	1	1	2	2	2	0	0
Total ASCE-CI	1	0	1	0	0	1	1	0	0
Total Federal	1	17	18	4	1	14	20	5	1
Total ODOT	0	0	2	8	0	0	6	1	3
Total PennDOT	1	8	10	14	1	7	22	5	1
Total	12	52	68	56	8	50	108	22	10
Percent of total	0.06	0.28	0.36	0.30	0.04	0.25	0.55	0.11	0.05

Group	Q 11 (% more i	Question 12(Increase in A/E fees a barrier?)				Question 13(Liability of Org. w.r.t DfCS)		
	Upto _% more in design fees to perform DfCS	DfCs will never happen due to increased fees by A/Es	Higher design fees could become acceptable	Increased design fees could be justified to higher management	No or modest increase in fees by A/Es	will increase liability exposure	will not affect liabililty exposure	decrease liability exposure
Total CII	2	0	0	2	2	0	1	3
Total COAA	16.5	1	2	0	2	3	2	1
Total ASCE-CI	20	0	2	0	0	0	2	0
Total Federal	93	7	14	13	6	11	13	16
Total ODOT	30.03	0	1	2	7	0	2	8
Total PennDOT	106	3	13	7	14	7	13	16
Total		22	64	48	62	42	66	88
Percent of total		0.11	0.33	0.24	0.32	0.21	0.34	0.45

Group	Question 14(Reasons for non-implementation of DfCS)						
	Not applicable	Too costly	Added design duration	No perceived benefit	Not enough information/ knowledge about DfCS	Higher priority for other project objectives	Other
Total CII	0	0	0	1	2	2	0
Total COAA	1	2	1	2	0	0	0
Total ASCE-CI	1	0	0	0	0	0	0
Total Federal	14	10	11	7	15	0	0
Total ODOT	3	1	0	0	3	2	0
Total PennDOT	11	10	11	2	8	6	0
Total	60	46	46	24	56	20	
Percent of total	0.24	0.18	0.18	0.10	0.22	0.08	

Group	Question 15(Org.'s priority criteria w.r.t construction projects)							
	Aesthetics	Construction worker safety & health	Facility user safety & health	Maintenance worker safety & health	Project cost	Project schedule	Quality of final product	Other
Total CII	18	7	16	12	10	13	5	0
Total COAA	24	30	18	24	9	20	16	0
Total ASCE-CI	7	14	10	12	2	7	4	0
Total Federal	208	136	143	194	118	152	154	0
Total ODOT	55	21	19	41	37	41	46	0
Total PennDOT	227	127	86	161	90	136	127	0
Total								
Percent of total								

Group	Question 16 (Change in the following items as a result of DfCS)							
	Construction injuries				Design costs			
	Decrease	No change	Increase	I don't know	Decrease	No change	Increase	I don't know
Total CII	3	0	0	0	0	0	1	2
Total COAA	3	2	0	1	0	1	5	0
Total ASCE-CI	2	0	0	0	1	0	1	0
Total Federal	33	2	1	5	1	1	34	5
Total ODOT	9	1	0	0	0	2	8	0
Total PennDOT	30	4	1	2	0	7	27	3
Total	160	18	4	16	4	22	152	20
Percent of total	0.81	0.09	0.02	0.08	0.02	0.11	0.77	0.10

Group	Question 16 (Change in the following items as a result of DfCS)							
	Construction costs				Total project costs to the owner			
	Decrease	No change	Increase	I don't know	Decrease	No change	Increase	I don't know
Total CII	3	0	0	0	2	1	0	0
Total COAA	0	4	1	1	1	1	4	0
Total ASCE-CI	2	0	0	0	1	0	0	1
Total Federal	6	8	22	5	4	6	27	4
Total ODOT	1	2	6	1	1	4	4	1
Total PennDOT	3	14	18	2	2	8	23	4
Total	30	56	94	18	22	40	116	20
Percent of total	0.15	0.28	0.47	0.09	0.11	0.20	0.59	0.10

Group	Question 16 (Change in the following items as a result of DfCS)							
	Design durations				Construction durations			
	Decrease	No change	Increase	I don't know	Decrease	No change	Increase	I don't know
Total CII	0	2	1	0	2	1	0	0
Total COAA	0	1	5	0	1	5	1	0
Total ASCE-CI	0	0	2	0	1	1	0	0
Total Federal	1	6	28	7	8	12	14	7
Total ODOT	0	5	5	0	0	6	3	1
Total PennDOT	0	9	25	2	0	18	16	2
Total	2	46	132	18	24	86	68	20
Percent of total	0.01	0.23	0.67	0.09	0.12	0.43	0.34	0.10

Group	Question 16 (Change in the following items as a result of DfCS)							
	Total design and construction durations				Construction quality			
	Decrease	No change	Increase	I don't know	Decrease	No change	Increase	I don't know
Total CII	2	1	0	0	1	0	2	0
Total COAA	0	2	4	0	0	5	1	0
Total ASCE-CI	0	0	1	1	0	2	0	0
Total Federal	3	10	23	5	0	15	14	11
Total ODOT	0	2	7	1	0	7	3	0
Total PennDOT	1	11	23	2	0	24	10	3
Total	12	52	116	18	2	106	60	28
Percent of total	0.06	0.26	0.59	0.09	0.01	0.54	0.31	0.14

Group	Question 16 (Change in the following items as a result of DfCS)							
	Number of lawsuits against owners				Number of lawsuits against A/Es			
	Decrease	No change	Increase	I don't know	Decrease	No change	Increase	I don't know
Total CII	2	1	0	0	2	0	1	0
Total COAA	2	1	2	1	1	2	2	1
Total ASCE-CI	0	2	0	0	0	1	1	0
Total Federal	17	4	7	13	11	2	15	13
Total ODOT	5	3	0	2	5	2	0	3
Total PennDOT	16	10	3	8	11	13	5	8
Total	84	42	24	48	60	40	48	50
Percent of total	0.42	0.21	0.12	0.24	0.30	0.20	0.24	0.25

Group	Question 16 (Change in the following items as a result of DfCS)			
	Reputation of A/Es within society			
	Decrease	No change	Increase	I don't know
Total CII	1	0	2	0
Total COAA	1	3	2	0
Total ASCE-CI	0	1	1	0
Total Federal	1	14	18	8
Total ODOT	0	4	4	2
Total PennDOT	0	10	17	10
Total	6	64	88	40
Percent of total	0.03	0.32	0.44	0.20

Group	Question 19 (Organization's category?)						Q 21(% of Org.'s market sector)	
	Owner	Designer(A/E)	Design/ Builder	GC/CM	Trade contractor	Other	Public sector(%)	Private sector(%)
Total CII	0	0	2	0	0	0	100	200
Total COAA	6	0	0	0	0	0	330	270
Total ASCE-CI	2	0	0	0	0	0	200	0
Total Federal	42	0	0	0	0	0	0	0
Total ODOT	11	0	0	0	0	0	1000	0
Total PennDOT	37	0	0	0	0	0	3700	0
Total	196	0	4	0	0	0		
Percent of total	0.98	0.00	0.02	0.00	0.00	0.00		

Group	Q 22 (No. of emplo	Question 23(% of Org.'s market segment)				Q 24 (% of IPD utilization)
	Organization hs approximately __ employees	Commercial(%)	Industrial(%)	Infrastructure/ heavy civil(%)	Residential(%)	% of organization's projects uses some type of integrated project delivery approach, e.g. deign-build/ CM at risk etc.
Total CII	36000	30	200	70	0	155
Total COAA	21761	332	95	41	32	195
Total ASCE-CI	650	60	0	140	0	5
Total Federal	0	0	0	0	0	0
Total ODOT	36500	0	0	1000	0	172
Total PennDOT	209663	0	0	3700	0	885.5
Total						
Percent of total						

Group	Q 25 (% constructed by O
	% of organization's projects constructed by organization's own employees
Total CII	35
Total COAA	15
Total ASCE-CI	33.5
Total Federal	0
Total ODOT	92
Total PennDOT	246
Total	
Percent of total	

Group	Question 26(Organization's facility locations)											
	Northeast U.S.	Mountain states	Midwest U.S.	Mid-Atlantic U.S.	Southwest U.S.	Europe	Southeast U.S.	West Coast	Caribbean	South America	Asia	Middle East & Africa
Total CII	3	3	3	2	3	2	3	2	1	3	2	2
Total COAA	2	0	5	0	0	0	1	1	0	0	0	0
Total ASCE-CI	1	1	0	0	0	0	0	0	0	0	0	0
Total Federal	0	0	0	0	0	0	0	0	0	0	0	0
Total ODOT	0	0	0	0	0	0	0	10	0	0	0	0
Total PennDOT	37	0	0	0	0	0	0	0	0	0	0	0
Total												
Percent of total												

Group	Question 19-Federal only (Role in the organiza		
	Facilities Manager	Project Manager	Environmental, health, safety, and fire
Total CII	0	0	0
Total COAA	0	0	0
Total ASCE-CI	0	0	0
Total Federal	9	22	8
Total ODOT	0	0	0
Total PennDOT	0	0	0
Total			
Percent of total			

Appendix 21: Recommended Changes to the EJCDC E-500 to Facilitate DfCS

Highlighting Legend:
***Yellow** indicates relevant for understanding the content and flow of the document.*
***Green** indicates directly relevant to safety issues.*
***Red** indicates suggested new or revised text*
Owner and Engineer agree as follows:

ARTICLE 1 - SERVICES OF ENGINEER

1.01 Scope

A. Engineer shall provide, or cause to be provided, the services set forth herein and in Exhibit A.

ARTICLE 6 - GENERAL CONSIDERATIONS

6.01 Standards of Performance

H. The General Conditions for any construction contract documents prepared hereunder are to be the "Standard General Conditions of the Construction Contract" as prepared by the Engineers Joint Contract Documents Committee (No. C-700, 2002 Edition) unless both parties mutually agree to use other General Conditions by specific reference in Exhibit J.

I. Engineer shall not at any time supervise, direct, or have control over Contractor's work, nor shall Engineer have authority over or responsibility for the means, methods, techniques, sequences, or procedures of construction selected or used by Contractor, for security or safety at the Site, for safety precautions and programs incident to the Contractor's work in progress, nor for any failure of Contractor to comply with Laws and Regulations applicable to Contractor's furnishing and performing the Work.

Notwithstanding the previous paragraph, Engineer shall attempt to consider the safety of construction and maintenance workers during the design of the Project. It is expressly acknowledged that: a) such consideration shall be only to the extent reasonable possible given that Engineer may be lacking knowledge of the means, methods, techniques, sequences or procedures of construction that the Contractor will use; b) it is impossible for the design to reduce or eliminate all hazards, c) the Contractor retains sole responsibility for the safety of construction workers even for portions of the project on which Engineer has attempted to reduce site hazards through design decisions; d) there will be portions of the Project on which Engineer has made no effort to reduce hazards through design decisions; and e) that discussions between Engineer and Contractor or any subcontractor regarding safety or other aspects of the design, shall not be construed to establish a contractual relationship between the Engineer and Contractor or any subcontractors.

6.10 Indemnification and Mutual Waiver

A. *Indemnification by Engineer*. To the fullest extent permitted by law, Engineer shall indemnify and hold harmless Owner, and Owner's officers, directors, partners, agents, consultants, and employees from and against any and all claims, costs, losses, and damages (including but not limited to all fees and charges of engineers, architects, attorneys, and other professionals, and all court, arbitration, or other dispute resolution costs) arising out of or relating to the Project, provided that any such claim, cost, loss,

or damage is attributable to bodily injury, sickness, disease, or death, or to injury to or destruction of tangible property (other than the Work itself), including the loss of use resulting therefrom, but only to the extent caused by any negligent act or omission of Engineer or Engineer's officers, directors, partners, employees, or Consultants. The indemnification provision of the preceding sentence is subject to and limited by the provisions agreed to by Owner and Engineer in Exhibit I, "Allocation of Risks," if any.

SUGGESTED FORMAT
(for use with E-500, 2002 Edition)

This is **EXHIBIT A**, consisting of _____ pages, referred to in and part of the **Agreement between Owner and Engineer for Professional Services** dated _____, _____.

Engineer's Services

Article 1 of the Agreement is amended and supplemented to include the following agreement of the parties. Engineer shall provide Basic and Additional Services as set forth below.

PART 1 – BASIC SERVICES

A1.01 Study and Report Phase

A. Engineer shall:

(*note: The inserted paragraphs below would need to be numbered 5 and the current paragraph numbered 5 and all following paragraphs would have to be renumbered.)*

4.5 Consult with Owner and/or Contractor regarding the constructability of the design, including whether aspects of the design can be made less hazardous through changes that will not significantly affect other project criteria.

A1.02 Preliminary Design Phase

(*note: The inserted paragraphs below would need to be numbered 7 and the current paragraph numbered 7 and all following paragraphs would have to be renumbered.)*

6.5. Consider revising Preliminary Design Phase documents in response to Contractor's comments regarding constructability, as appropriate and as approved by Owner.

Appendix 22: Suggested Changes to the EJCDC E-700 to Facilitated DfCS

Highlighting Legend:
***Yellow** indicates relevant for understanding the content and flow of the document.*
***Green** indicates directly relevant to safety issues.*
***Red** indicates suggested new or revised text*

ARTICLE 1 – DEFINITIONS AND TERMINOLOGY

1.07 *Safety and Protection*

A. Contractor shall be solely responsible for initiating, maintaining and supervising all safety precautions and programs in connection with the Work. Such responsibility does not relieve Subcontractors of their responsibility for the safety of persons or property in the performance of their work, nor for compliance with applicable safety Laws and Regulations. Contractor shall take all necessary precautions for the safety of, and shall provide the necessary protection to prevent damage, injury or loss to:

1. all persons on the Site or who may be affected by the Work;

2. all the Work and materials and equipment to be incorporated therein, whether in storage on or off the Site; and

3. other property at the Site or adjacent thereto, including trees, shrubs, lawns, walks, pavements, roadways, structures, utilities, and Underground Facilities not designated for removal, relocation, or replacement in the course of construction.

B. Contractor shall comply with all applicable Laws and Regulations relating to the safety of persons or property, or to the protection of persons or property from damage, injury, or loss; and shall erect and maintain all necessary safeguards for such safety and protection. Contractor shall notify owners of adjacent property and of Underground Facilities and other utility owners when prosecution of the Work may affect them, and shall cooperate with them in the protection, removal, relocation, and replacement of their property.

C. Contractor shall comply with the applicable requirements of Owner's safety programs, if any. The Supplementary Conditions identify any Owner's safety programs that are applicable to the Work.

D. Contractor shall inform Owner and Engineer of the specific requirements of Contractor's safety program with which Owner's and Engineer's employees and representatives must comply while at the Site.

E. All damage, injury, or loss to any property referred to in Paragraph 6.13.A.2 or 6.13.A.3 caused, directly or indirectly, in whole or in part, by Contractor, any Subcontractor, Supplier, or any other individual or entity directly or indirectly employed by any of them to perform any of the Work, or anyone for whose acts any of them may be liable, shall be remedied by Contractor *(except damage or loss attributable to the fault of Drawings or Specifications or to the acts or omissions of Owner or Engineer* or anyone employed by any of them, or anyone for whose acts any of them may be liable, and not attributable, directly or indirectly, in whole or in part, to

the fault or negligence of Contractor or any Subcontractor, Supplier, or other individual or entity directly or indirectly employed by any of them). Comment: should the italicized text be modified to reduce chance of attorney arguing that that this clause applies of to an Engineer's omission of reducing hazard that contributed to an injury.

F. Contractor's duties and responsibilities for safety and for protection of the Work shall continue until such time as all the Work is completed and Engineer has issued a notice to Owner and Contractor in accordance with Paragraph 14.07.B that the Work is acceptable (except as otherwise expressly provided in connection with Substantial Completion).

1.02 *Safety Representative*

A. Contractor shall designate a qualified and experienced safety representative at the Site whose duties and responsibilities shall be the prevention of accidents and the maintaining and supervising of safety precautions and programs.

1.03 *Hazard Communication Programs*

A. Contractor shall be responsible for coordinating any exchange of material safety data sheets or other hazard communication information required to be made available to or exchanged between or among employers at the Site in accordance with Laws or Regulations.

ARTICLE 4 – ENGINEER'S STATUS DURING CONSTRUCTION

4.01 *Owner's Representative*

A. Engineer will be Owner's representative during the construction period. The duties and responsibilities and the limitations of authority of Engineer as Owner's representative during construction are set forth in the Contract Documents.

4.02 *Visits to Site*

A. Engineer will make visits to the Site at intervals appropriate to the various stages of construction as Engineer deems necessary in order to observe as an experienced and qualified design professional the progress that has been made and the quality of the various aspects of Contractor's executed Work. Based on information obtained during such visits and observations, Engineer, for the benefit of Owner, will determine, in general, if the Work is proceeding in accordance with the Contract Documents. Engineer will not be required to make exhaustive or continuous inspections on the Site to check the quality or quantity of the Work. Engineer's efforts will be directed toward providing for Owner a greater degree of confidence that the completed Work will conform generally to the Contract Documents. On the basis of such visits and observations, Engineer will keep Owner informed of the progress of the Work and will endeavor to guard Owner against defective Work.

B. Engineer's visits and observations are subject to all the limitations on Engineer's authority and responsibility set forth in Paragraph 9.09. Particularly, but without limitation, during or as a result of Engineer's visits or observations of Contractor's Work, Engineer will not supervise, direct, control, or have authority over or be

responsible for Contractor's means, methods, techniques, sequences, or procedures of construction, or the safety precautions and programs incident thereto, or for any failure of Contractor to comply with Laws and Regulations applicable to the performance of the Work.

4.09 *Limitations on Engineer's Authority and Responsibilities*

A. Neither Engineer's authority or responsibility under this Article 9 or under any other provision of the Contract Documents nor any decision made by Engineer in good faith either to exercise or not exercise such authority or responsibility or the undertaking, exercise, or performance of any authority or responsibility by Engineer shall create, impose, or give rise to any duty in contract, tort, or otherwise owed by Engineer to Contractor, any Subcontractor, any Supplier, any other individual or entity, or to any surety for or employee or agent of any of them.

B. Engineer will not supervise, direct, control, or have authority over or be responsible for Contractor's means, methods, techniques, sequences, or procedures of construction, or the safety precautions and programs incident thereto, or for any failure of Contractor to comply with Laws and Regulations applicable to the performance of the Work. Engineer will not be responsible for Contractor's failure to perform the Work in accordance with the Contract Documents.

C. Engineer will not be responsible for the acts or omissions of Contractor or of any Subcontractor, any Supplier, or of any other individual or entity performing any of the Work.

4.10 *Compliance with Safety Program*

A. While at the Site, Engineer's employees and representatives shall comply with the specific applicable requirements of Contractor's safety programs of which Engineer has been informed pursuant to Paragraph 6.13.D.

Appendix 23: Recommended Changes to the IPD Agreement to Facilitate DfCS

Excerpts from the
Integrated Agreement for Lean Project Delivery Between Owner, Architect & CM/GC

This document includes excerpts from the IPD agreement being used on the Hospital Project case study that are related to construction safety. The italicized text are suggested changes to the agreement if design for construction safety was to be explicitly implemented on the project.

11.3. Constructability. The IPD Team shall continually review the Design Documents for clarity, consistency, constructability and coordination among the construction trades and collaborate with the IPD Team in developing solutions to any identified issues. The purpose of the Constructability Reviews is to determine that the design is progressing in a manner that will result in complete, accurate and coordinated drawings which are sufficiently complete and coordinated for construction, and thereby reduce the risk of disruption, delay, *injuries*, change orders and potential claims. CM/GC and the Subcontractors will focus on accuracy, completeness, sequencing and coordination. These reviews will also seek out alternative construction materials, sequences, details, pre-fabrication opportunities, and systems that may result in a cost or time savings to Owner, or increased quality *and safety and health*. Nothing in this section shall relieve Architect, CM/GC or any Subcontractor, Supplier or Architect's Consultant from its obligation to perform its services or work in accordance with the terms of its contract and the applicable standard of care.

16.5. Means and Methods. Architect will neither have control over or charge of, nor be responsible for, the construction means, methods, techniques, sequences or procedures, or for safety precautions and programs in connection with the Work, since these are solely CM/GC's and Subcontractor's rights and responsibilities under the Contract Documents, except as expressly provided elsewhere. *Notwithstanding the previous sentence, it is acknowledged that the Architect is expected to participate in discussions relating to constructability while design is occuring.* Architect will not be responsible for CM/GC's failure to perform the Work in accordance with the requirements of the Contract Documents. Architect will neither have control over or charge of, nor be responsible for, acts or omissions of CM/GC, Subcontractors, or their agents or employees, or of any other persons performing portions of the Work.

20. SAFETY PRECAUTIONS AND PROGRAMS

20.10. Architect's Role. *Notwithstanding the previous paragraphs, Architect is expected to participate in discussions relating to constructability, including aspects relating to safety, while design is occurring.* Architect's review of CM/GC's performance does not include review of adequacy of CM/GC's safety measures.

*(The paragraph below is a new paragraph that is modeled on paragraph 25 "**QUALITY OF THE WORK AND SERVICES**" in the agreement.)*

25B. PROJECT SAFETY AND HEALTH

25B.1. Safety Initiative. The goal of Lean Project Delivery is production of defect-free work at the least cost, in the least time possible and without posing unnecessary risk to project personnel. Recognizing and avoiding risks that could have been designed out in the first place is costly both in time and dollars and is not a value-adding activity. While it is recognized that construction is an inherently dangerous process, safety and health should be considered during

the design phase and the resulting design should be as safe to implement as reasonably possible.

25B.2. Design for Safety Plan. Architect and CM/GC, in collaboration with other IPD Team Members, shall participate and develop a design for safety plan that, at a minimum, addresses the following issues:
25B.2.1. Confirming that the Contract Documents adequately communicate that design for safety will be part of the Project'
25B.2.2. Training project personnel on design for safety concept and the potential consequences of design processes that fail to consider the safety of construction workers;
25B.2.3. Providing design and construction personnel with relevant design for safety checklists and other available tools;
25B.2.4. Design of feed-back mechanisms for on-site managers and corporate safety managers to review early work product and assure completion according to conditions of satisfaction;
25B.2.5. Integration of safety review and management with hand-off criteria and the Six Week Look Ahead Plan;
25B.2.6. Protocols for trades to discuss and assure a safe working environment;
25B.2.7. Procedures for immediately discussing injuries and other safety-related incidents
25B.2.8. Procedures for recognizing outstanding performance and safety according to the conditions of satisfaction;

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